ACCEPTANCE, ATTITUDES AND NUTRITIONAL CONTENT OF NOVEL NIXTAMALIZED MAIZE PRODUCTS DEVELOPED FOR THE SOUTH AFRICAN CONSUMER

by

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''GREAT THINGS ARE DONE BY A SERIES OF SMALL THINGS BROUGHT TOGETHER''

-VINCENT VAN GOGH

DECLARATION

I, Taylon Anthony Colbert, declare that the thesis titled, **''ACCEPTANCE, ATTITUDES AND NUTRITIONAL CONTENT OF NOVEL NIXTAMALIZED MAIZE PRODUCTS DEVELOPED FOR THE SOUTH AFRICAN CONSUMER''**, hereby submitted for the Master of Science degree in the Department of Sustainable Food Systems and Development at the University of the Free State, is my own independent work, and that I have not previously submitted the same work for a qualification at another institution of higher education.

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ABSTRACT

South Africa is well-known for its good quality maize that serves as a staple crop for over 80% of the country’s population. Additionally, South Africa is also Africa’s top maize producer. However, maize provides an unbalanced supply of essential nutrients, such as the essential amino acids lysine and tryptophan. Moreover, the water-soluble vitamin B_3 is biologically unavailable to humans. Therefore, long-term consumption of maize-based diets, deficient in these nutrients, can result in pellagra, a disease manifested by the characteristic symptom dermatitis, on sun-exposed skin. The process of nixtamalization improves the nutritional, textural and sensory quality, and the physicochemical properties of maize products. Nixtamalization is the traditional process of preparing maize in Mexico. It involves cooking and soaking maize kernels in an alkaline solution, typically calcium hydroxide or slaked lime. The process allows bound nutrients to be more readily available for absorption, improves flavour and texture, as well as digestion. This study was divided into three essential phases: (I) the development of consumer-acceptable novel nixtamalized maize products; (II) the determination of consumer attitudes, knowledge and awareness towards nixtamalization and nixtamalized maize products, through the administration of a questionnaire; and (III) the analysis of the nutritional content of a novel consumer accepted nixtamalized maize product.

The first phase aimed to explore South African consumers' acceptance of nixtamalization and novel nixtamalized maize products. Three nixtamalized maize products were developed: a vegetarian patty; a vegetarian nugget; and a maize chip. To evaluate the consumers' sensory acceptance of various attributes, including taste, aroma, texture, and appearance, the study employed the Just-About-Right (JAR) scales and a 9-point hedonic scale. Among the three products evaluated, the maize chip received the most acceptable JAR results, although improvements were required for its appearance attribute. Furthermore, correlation and penalty analysis revealed that appearance and taste played significant roles in the acceptance of nixtamalized maize products, among South African consumers. Consequently, the chips were flavoured with seasonings to improve taste and appearance, with different flavours, such as chutney and tomato. Notably, the chutney-flavoured maize chip achieved an acceptance rate of >70.0% for all four attributes, rendering it “just-about-right”.

The study's second phase involved determining consumers’ attitudes toward nixtamalization and nixtamalized maize products. The data was collected online, using an Evasys© questionnaire, which was anonymously completed by respondents, during the sensory tasting of the maize chips. Quantitative analysis concluded that most respondents were open to nixtamalization as a new processing technique and to newly developed maize products produced, through nixtamalization. Specifically, respondents indicated that the safety aspect of nixtamalization played a crucial role in their willingness to consume nixtamalized maize, in the future. Moreover, the results indicated that the respondents were willing to incorporate nixtamalized products into their future consumption, and recommend them to friends and family.

After achieving consumer acceptance, the third phase of the study focused on conducting nutritional analysis of the novel nixtamalized maize chip. The analysis revealed several noteworthy findings. The chips exhibited a high energy content of 2303 kJ/100 g and protein content of 6.64 g/100 g. Compared to two commercial chips, the nixtamalized maize chip displayed a higher insoluble fibre content of 15.87 g/100 g of NDF and 1.32 g/100 g of ADF. Additionally, the sodium content of the maize chip (706.67 mg/100 g), fell within the permissible limit set out by South African salt legislation (<800 mg/100 g), for savoury snack foods. Moreover, the chips demonstrated favourable potassium, calcium, phosphorus, and magnesium levels. The higher fat content of 23.72 g/100 g in the chips was attributed to the deep-frying process, used during preparation.

Keywords: maize; staple; nixtamalization; consumer acceptance; Just-about-Right, JAR; 9-point hedonic scale; consumer-liking; sensory analysis; consumer attitudes; pellagra; malnutrition; food security; nutrition security; maize chip; product development.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

SSA	Sub-Saharan Africa
NIH	Nixtamalization using infrared heating
QPM	Quality Protein Maize
%	Percentage
° C	Degree Celsius
W/g	Watts per gram
$Ca(OH)_2$	Calcium hydroxide
JAR	Just-About-Right
DAFF	Department of Agriculture, Forestry and Fisheries
GHREC	General/Human Research Ethics Committee
UFS	University of the Free State
FSP	Free State Province
RSA	Republic of South Africa
PTY Ltd	Proprietary Limited Company
FAME	Fatty Acid Methyl Ester
FAs	Fatty Acids
SFA	Saturated Fatty Acids
MUFAS	Monosaturated Fatty Acids
PUFAS	Polyunsaturated Fatty Acids
AOAC	Association of Official Agricultural Chemists
ASM	Analytical Standard Method
g	Grams
mg	Milligrams
mj	Megajoules
kj	Kilojoules
DM	Dry matter
NDF	Neural Detergent Fibre
ADF	Acid Detergent Fibre
FFDM	Fat-Free Dry Matter
ADS	Acid Detergent Solution

µl	Microlitre
Psi	Per square inch
ppm	Parts per million
Min	Minute
n-6	Omega 6
n-3	Omega 3
EPA	Eicosapentaenoic acid
nm	Nanometer
mA	Milliampere
UK	United Kingdom
WHO	World Health Organisation
FAO	Food and Agricultural Organisation
DNA	Deoxyribonucleic Acid
SADC	Southern African Development Community
β	*Beta*
α	*alpha*
VAD	Vitamin A deficiency
MON	Moniliformin
StatsSA	Statistics South Africa
et al	et alia / and others
pH	Potential of Hydrogen / scale of acidity from 0 to 14
AFMA	Animal Feed Manufacturers Association
USA	United States of America
DRC	Democratic Republic of the Congo
USDA	United States Department of Agriculture
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CHAPTER 1: INTRODUCTION

1.1 GENERAL INTRODUCTION AND SIGNIFICANCE OF THE STUDY

Maize (*Zea mays, L.*), also known as corn, belongs to the grass family Poaceae (*Gramineae*) (Mazvimbakupa, Modi and Mabhaudhi, 2015). Typically, wheat, maize and rice are the most important human food sources, making up 94% of all cereals consumed worldwide, with maize being the major staple crop on the African continent (Ranum, Peña-Rosas and Garcia-Casal, 2014; Kruger, Van Rensburg and Van den Berg, 2009). Furthermore, maize plays an important role in reducing the prevalence of poverty, as well as improving the food security status of lower-income families in Sub-Saharan Africa (Zuma, Kolanisi and Modi, 2018; Hu, Burucs and Schmidhalter, 2008). More specifically, South Africa also serves as the primary source of food for the Southern African Development Community (SADC) region, as it produces 50% of the crop (FAO, 2014).

Notably, maize is widely acknowledged for playing a critical role in ensuring food security and sustaining the overall economic growth of South Africa, as it generates an estimated R9.4 billion annually (Adisa *et al.,* 2018). Furthermore, the crop has displayed a steady annual 3% increase in demand (Durand, 2006). Maize is particularly known to be a rain-fed summer crop; however, 60% of South Africa's maize is produced in the country's semi-arid regions of the Free State and North West provinces. Mpumalanga and Kwa-Zulu Natal provinces follow, with 24% and 5%, respectively (Adisa *et al.,* 2018; Molua and Lambi, 2006). In addition to producing a significant amount of the crop for greater Southern Africa, the crop itself serves as a staple for the South African population, more specifically the lower-income communities (Abidoye and Mabaya, 2014; Gause, 2013). According to Vermeulen *et al*. (2005), maize consumption between humans and animals differs, as white maize is primarily produced for human consumption, while yellow maize is used for animal feed. It is important to note that the consumption of white maize differs among rural and urban consumers in South Africa; rural consumers generally consume maize as the dominant staple, while most urban consumers consume it either as a staple or as a variety-giving component, within a balanced meal (Vermeulen *et al*., 2005).

However, Govender (2014) suggests that the consumption of maize could exaggerate issues of food and nutrition insecurity, if consumed in isolation without a diversified diet. This is particularly relevant for rural communities in South Africa, where a predominant reliance on maize and maize-based dishes exists without variety, consequently leading to imbalanced nutrition. This may be due to the presence of the resistant starch phytate in maize, which acts as an anti-nutritional factor, by binding to essential nutrients, consequently hindering the availability for digestion and absorption in the body (Mabhaudhi, Modi and Beletse, 2013). Furthermore, conventional processing techniques commonly result in the removal of the pericarp and germ during food preparation, leading to the loss of key nutrients, such as proteins, lipids, minerals, vitamins and essential amino acids, such as lysine and tryptophan (Ranum, Peña-Rosas and Garcia-Casal, 2014). It is important to note that efforts have been made at industrial level to improve the nutritional value of maize, by creating biofortified varieties that contain higher levels of provitamin A, zinc or protein (Bouis and Saltzman, 2017). Despite this, processing methods, which can be employed by households and street vendors, to improve the nutritional profile of this staple have largely been neglected (Ekpa *et al*., 2018). Hence, there is a need for cost-effective processing techniques that can improve the nutrient composition of maize and maize-based products, particularly considering the reliance of lower-income communities on this staple food. An approach to processing maize that has the potential to increase its nutritional value, without specialised equipment, is nixtamalization, which is a traditional processing technique used in Mexico, but is not widely recognised in Africa (Ekpa *et al*., 2018).

The process of nixtamalization involves cooking maize kernels in an alkaline-aqueous solution of calcium hydroxide or slaked lime, followed by soaking between eight and 24 hours. Thereafter, the soaked kernels are thoroughly rinsed to remove pericarp and residual alkali, known as nejayote (Argun and Argun, 2018). After rinsing, the maize is called nixtamal, which can be ground to form a pliable dough, known as masa, or dried and ground into maize meal or flour (GrainSA, 2019). The process also provides many nutritional benefits that the maize kernel lacks, such as increased niacin bioavailability, which decreases the risk of pellagra, higher calcium intake as a result of the steeping process with calcium hydroxide, increased dietary fibre by elevating the content of resistant starch, a significant reduction in mycotoxin levels, and diminished levels of phytic acid, which inhibits the bioavailability of iron and zinc (Serna-Saldivar, 2016; Bressani, Turcios and de Ruiz, 2002). Additionally, nixtamalization leads to an increase in the essential amino acids lysine and tryptophan (Escalante-Aburto *et al.,* 2020). Therefore, the combination of this method, with conventional processing techniques in Africa, can help to alleviate the issue of aflatoxin contamination, which is still a serious concern and poses a barrier to achieving food and nutrition security (Ekpa *et al*., 2018).

The aim of the study was to develop nixtamalized maize products that were both nutritionally beneficial and acceptable to the South African consumer, using product development, sensory and nutritional analysis. In addition, the study aimed to determine consumer attitudes towards nixtamalization, as a novel food processing technique, by administering a questionnaire to gather valuable insights.

Once the aim was established, research questions were formulated, based on the researcher’s curiosity to achieve the aim. The following proposed questions were asked, with the intention of providing clarity and insight, to ensure that no aspect of the aim was overlooked during the investigation of the study.

1. What gaps in the current state of knowledge on nixtamalization could be addressed in the South African context, through a comprehensive literature study?
2. What sensory attributes influence the acceptability of nixtamalized maize products among South African consumers?
3. How can these attributes be incorporated into product development formulations, to optimise consumer acceptability?
4. What are the attitudes and perceptions of South African consumers towards nixtamalization, as a novel food processing technique?
5. How can these attitudes affect consumers’ willingness to consume nixtamalized maize products in the future?
6. How does the nutritional profile of nixtamalized maize products compare to those of other commonly consumed maize products in South Africa?
7. What impact can the nutritional benefits of nixtamalization have on public health and nutrition status?

8. How can main findings of the study contribute to a broader academic discussion on nixtamalization and its potential impact on food processing, product development and consumer health?

The researcher prioritised the development of the research questions over the objectives, as the former served as the foundation for formulating the latter. Therefore, by formulating the research questions first, the researcher was able to establish five definitive objectives that would guide the study towards achieving the aim.

1. The first objective of the study was to conduct a comprehensive literature study, which consisted of a thorough review of the existing literature on nixtamalization. This objective was derived from the first research question, which aimed to determine how nixtamalization could be contextualized within the South African setting. It involved analysing relevant information from various sources, such as peer-reviewed articles, books and other scholarly works. The goal of the literature study was to gain a deeper understanding of the current state of knowledge on the subject and to identify any gaps that could be addressed in the South African context. Additionally, this step was crucial in the research design and methodology, to ensure that the study objectives were addressed effectively.

2. The second objective of the study involved the development of novel nixtamalized maize products that would cater specifically to the South African consumer. This entailed the development of the formulation of new products that would meet the sensory preferences of the consumer. To achieve this, sensory analysis techniques were used, to evaluate the acceptability of the newly developed maize products, in terms of appearance, aroma, taste, texture and overall consumer liking. This objective was formulated to provide meaningful insights into the second and third research questions, which aimed to determine the sensory attributes which influence consumers' acceptance of new products and how these attributes could be used, in the development of new products.

3. The third objective of the study was derived from the fourth and fifth research questions, which sought to investigate the attitudes and perceptions of South

African consumers towards nixtamalization, as well as their willingness to consume nixtamalized maize products. In addition, the third objective aimed to determine knowledge and awareness among consumers, regarding nixtamalization, newly developed products, and growing and processing of their own crops. This was determined through an electronic questionnaire that was quantitatively analysed. The data, gathered from the questionnaire, provided insights into consumer preferences, behaviours and attitudes towards nixtamalization and nixtamalized maize products.

4. The fourth objective of this study aimed to determine and compare the nutrient content of the novel nixtamalized maize products, developed in the second objective, to similar non-nixtamalized products. This objective was derived from research questions six and seven, which aimed to determine the nutrient profile of nixtamalized products, as well as the nutritional benefits it may offer. Thorough nutritional analysis was carried out and the results were discussed and compared to other common products. This objective aimed to determine if there were differences in the nutritional content between the nixtamalized products and other non-nixtamalized products, which could have an impact on consumer health and wellbeing. The purpose of comparing the nutritional content in the study aimed to determine if nixtamalization could be a viable processing technique, for enhancing the nutritional value of maize-based products in South Africa.

5. The final objective of the study was to present a clear, concise and informative conclusion of the findings, highlighting the main points and their significance. By achieving this objective, the study could contribute to the broader academic discussion on nixtamalization and its potential impact on food processing and consumer health.

Figure 1.1 displays a graphical overview of the study, which aims to provide a comprehensive snapshot of the research conducted, including its data collection methods, progress and overall structure.

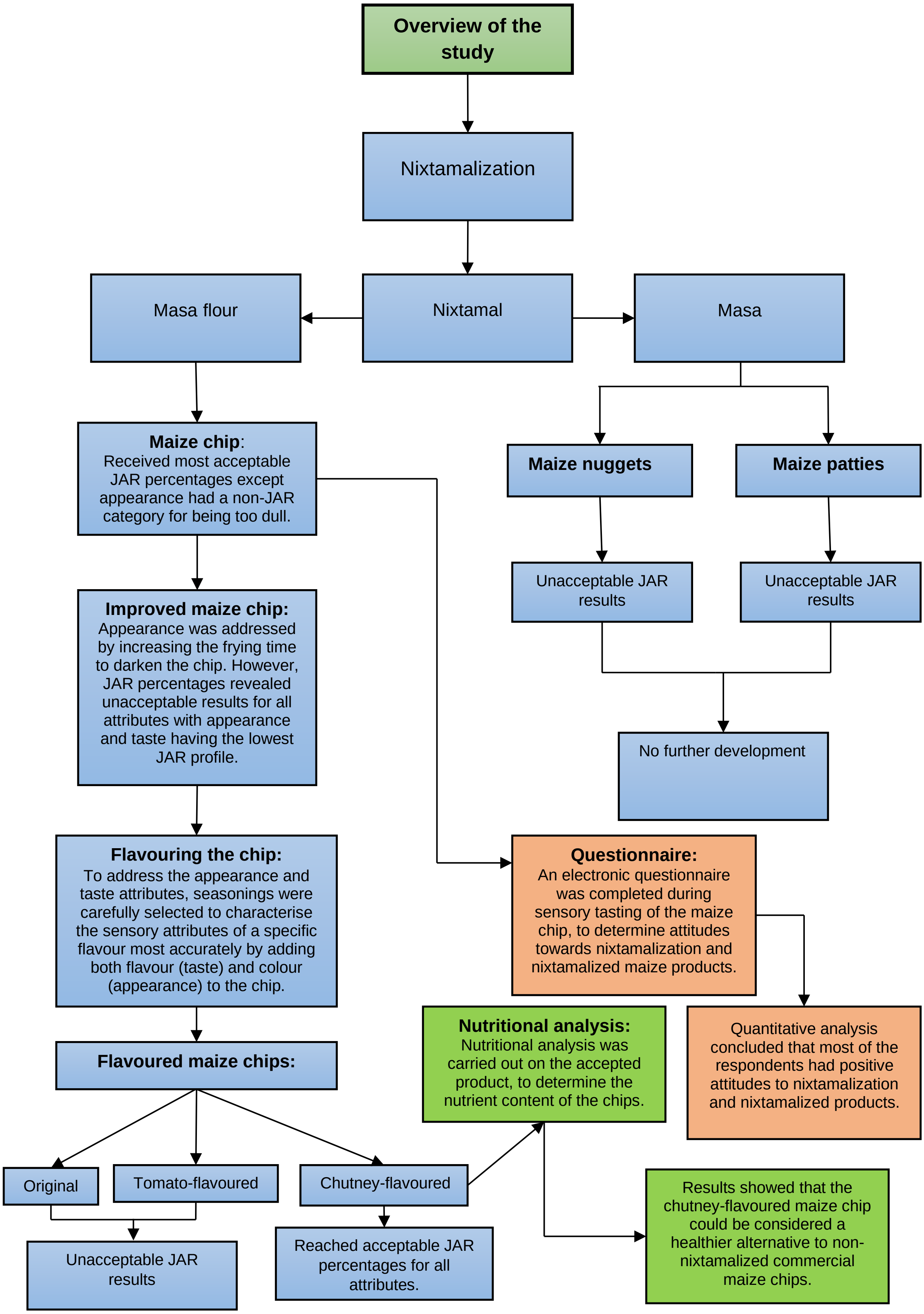

Figure 1.1: Overview of the study.

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CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION AND BACKGROUND

Cereal grains, derived from cultivated grasses, offer humanity a more significant nutritional contribution, compared to any other food category, fulfilling nearly half of the total energy needs. Among the various cereal crops used for sustenance, wheat, maize and rice stand out as the primary sources of essential human food, constituting 94% of the overall cereal consumption (Ranum, Peña-Rosas, and Garcia-Casal, 2014). The consumption patterns of these cereal crops exhibit significant regional variations. Wheat emerged as the preferred cereal in Central Asia, the Middle East, South and North America, and Europe. Rice, on the other hand, holds the primary position as the most consumed cereal in Asia. Prominently favoured maize finds its place in Southern and Eastern Africa, Central America and Mexico (Ranum, Peña-Rosas, and Garcia-Casal, 2014). Maize (*Zea mays*), also called corn, is believed to have originated in central Mexico, between 7000 and 10 000 years ago, from a wild grass called *teosinte,* and Native Americans transformed maize into a better source of food (Figure 2.1) (Ranum, Peña-Rosas, and Garcia-Casal, 2014).

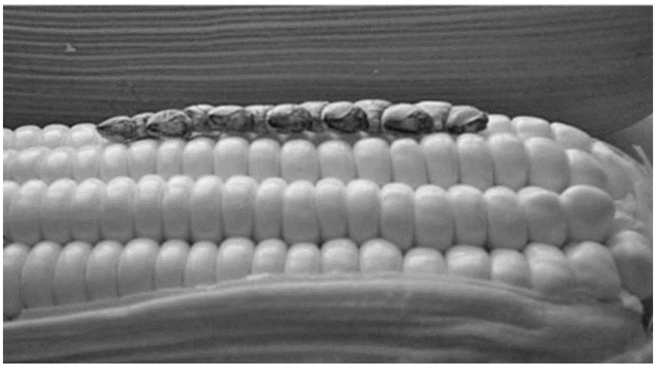

Figure 2.1: Photograph of the modern maize cob (bottom) compared to its ancestor *Teosinte* (top) (courtesy of Dr Juan Manuel de la Fuente).

The oldest paleo-ethnobotanical evidence of maize domestication is in the archaeological site of Nac Neish, located in the southern part of Tamaulipas, Mexico (Serna-Saldivar, 2016). The evolution of the breeding methods of maize (*Zea mays* L.) is similar to other major cultivated crop species. Plant breeding started when humans transitioned from hunter-gatherers to living in more populated and organised societies. The need for food, feed, fibre, and fuel for the citizens in these organised societies became a prominent and basic need. The plants, within the surrounding indigenous vegetation, were observed and selected to meet the population's needs. The plants were highly adapted to the environmental conditions and survived with little human intervention. The choice of plant species depended on the available plant's prevalence, ability to survive in the environmental conditions and the people's needs. The selection of plants was different in different areas of the world, where human civilisation started (Hallauer and Carena, 2009).

Maize is one of the few major cultivated crop species that originated in the Western Hemisphere, in the highlands of southern Mexico and Guatemala. Like other crop species, maize arose from a wild, weedy species, native to the area. Collective findings during the past 60 years suggest that teosinte (*Zea mays* L.: ssp. Mexicana) was the putative parent of modern-day maize (Wilkes, 2004). Although the transition from a wild to a modern cultivated species was similar to other crops in many aspects, maize has had some different properties, other than its origin in the Western Hemisphere. Maize is a cross-pollinated species with unique and separate male (tassel) and female (ear) organs. Maize breeding has unique features that are different from the other extensively cultivated grain species, such as rice (*Oryza sativa*), wheat (*Triticum vulgare*) and oats (*Avena sativa*), which are primarily self-pollinated. Techniques from self- and cross-pollinated crops are used to produce maize (Hallauer, Miranda-Filho and Carena, 2010).

Maize contains about 72% starch, 10% protein and 4% fat. Maize provides many B vitamins and essential minerals, along with fibre, but lacks some other nutrients, such as vitamin B_{12} and vitamin C, and is generally a poor source of calcium, folate and iron. However, one limitation of maize is that while it contains the vitamin niacin, it is in a bound form that is not readily available to the body. It is also low in tryptophan, a niacin precursor. In order for niacin to be released from the bound form, it needs to have the pH increased, before entering the low pH of the stomach (Ranum, Peña-Rosas, and Garcia-Casal, 2014). Early natives in Latin America stumbled upon a process called nixtamalization, which involved cooking and soaking whole maize kernels in an alkaline solution of calcium hydroxide [$Ca(OH)_2$], also commercially known as slaked lime. Figure 2.2 provides a graphical structure of a maize kernel, which consists of the endosperm, embryo, pericarp and tip cap. The endosperm contains the main carbohydrates. The embryo contains the parts that give rise to the next generation, while the pericarp and tip cap encloses the entire kernel.

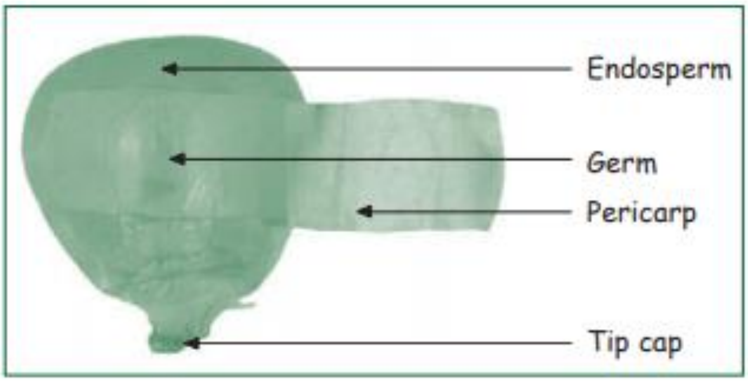

Figure 2.2: Structure of a maize kernel (Du Plessis, 2003).

According to Du Plessis (2003), the starch part of the kernel is used in foods and many other products, such as adhesives, clothing, pharmaceutical tablets and paper production. The starch can be converted into sweeteners and used in products, such as soft drinks, sweets, bakery products and jams. The oil from the embryo is used in cooking oils, margarine and salad dressings. The protein, hulls and soluble parts of the maize kernel are used in animal and poultry feed (Du Plessis, 2003).

2.2 NUTRITIONAL COMPOSITION OF MAIZE

Unfortunately, even though maize kernels supply many macronutrients and micronutrients, necessary for human metabolic needs, essential nutrients are unbalanced or inadequate for consumers, relying on maize as a primary food source (Nuss and Tanumihardjo, 2010). For instance, maize kernels lack the essential amino acids lysine and tryptophan and are deficient in vitamin C, B vitamins, iron and iodine (Galani *et al*., 2022). Furthermore, malnutrition continues to persist in poverty-stricken countries, particularly sub-Saharan Africa (Akombi *et al*., 2017). According to Nuss and Tanumihardjo (2010), food-based approaches, such as exogenous and endogenous maize fortification, provide promising evidence for significantly improving the health of numerous individuals in the fight against undernutrition.

2.2.1 Macronutrients

I. Carbohydrates

Starch is maize’s primary carbohydrate and kernel constituent. Sugars range from 1% to 3%, with sucrose as the chief component and maltose, glucose, fructose and raffinose in insignificant amounts. These sugars are almost exclusively located in the germ, with only 25% present in the endosperm. On the other hand, the wealth of kernel starch is found in the endosperm (Table 2.1). These complex carbohydrates consist of two glucose polymers, amylose and amylopectin. The ratio of amylose to amylopectin is usually 25:75, although genetic modifications can alter this ratio (Nuss and Tanumihardjo, 2010).

Table 2.1: Proximate chemical analysis of the main parts of maize kernels (%) (FAO, 1992).

Chemical component	Pericarp	Endosperm	Germ
Protein	3.7	8.0	18.4
Ether extract	1.0	0.8	33.2
Crude fibre	86.7	2.7	8.8
Ash	0.8	0.3	10.5
Starch	7.3	87.6	8.3
Sugar	0.35	0.62	10.8

II. Fibre

Crude fibre is highly characteristic of the kernel seed coat (87% of the seed coat), but is also found in smaller amounts in the endosperm and germ walls. Seed coat fibers include 67% hemicellulose, 23% cellulose and 0.1% lignin. Fibre makes up about 7% of the total kernel composition. In common maize varieties, the percentage of insoluble fibre is generally 12%, while soluble fibre is less than 2%. Maize fibre, with 89% dietary fibre (0.5 kcal/g), is a low-calorie alternative, compared to other high-fibre lipid-lowering products, like wheat bran with 49% dietary fibre (2 kcal/g). The fibre content of processed, dehulled kernels is drastically lower than that of whole-grain options, because fibre is concentrated in the seed coat, also called the pericarp (Table 2.1) (Nuss and Tanumihardjo, 2010).

III. Protein

Maize kernels contain about 10% protein, mainly distributed between the endosperm and the germ (Table 2.1). The endosperm has a lower protein concentration than kernel germ, but provides the highest quantity. Crude maize protein, often estimated by nitrogen content, consists of a mixture of prolamins, glutelins, albumins and globulins, which are differentiated by solubility properties. Amino acid profiles of each protein fraction are unique. Levels of prolamin, also referred to as zein, strongly indicate overall protein quality in maize, providing half the kernel nitrogen (Wilson, 1987). As prolamin levels accumulate in the endosperm during kernel maturation, total protein quality decreases, because zein proteins are low in lysine and tryptophan, essential amino acids for human survival (Gibbon and Larkins, 2005). Even though maize contains some lysine (0.150−0.250%) and tryptophan (0.030−0.040%), it is not sufficient for maize to be considered a high-quality protein source (Chand *et al.,* 2022; Nuss and Tanumihardjo, 2010).

IV. Lipids

Next to starch and protein, fat, in the form of oil, is the third most significant nutritional component of the kernel, ranging from 3.5% to 6% of total kernel weight, with an average of 4.5%. The germ houses the most concentrated amounts of lipids, nearly 85% of the total kernel oil; however, the germ is only about one-third oil (Table 2.1). Triacylglycerol is the primary storage form of kernel lipid. Lipids include phospholipids, sterols, waxes, alcohols and hydrophobic micronutrients. Compared with the fat content of other foods, such as sunflower seeds (51 g/100 g), whole-kernel maize is relatively low in fat (5 g/100 g). Maize oil contains predominantly unsaturated fatty acids, with an average of 60% linoleic, 24% oleic and 11% palmitic acid, although these ratios can vary in different agricultural regions (Nuss and Tanumihardjo, 2010). Its high linoleic acid content makes corn oil readily marketable as a superior product with 'heart healthy' benefits (Krauss *et al.*, 2000). A moderate dietary intake of 5 to 15 g of corn oil per day meets most people's essential fatty acid requirement and one tablespoon supplies 15% of the daily vitamin E requirement (Orthoefer, Eastman and List, 2003). Corn oil also aids in the absorption of other dietary fats and fat-soluble vitamins. Populations that consume maize as a primary food source are recommended to eat whole-kernel products, to take advantage of the healthy germs (Nuss and Tanumihardjo, 2010).

2.2.2 Micronutrients

I. Vitamins

Vitamins can be categorized into two major groups: fat-soluble (vitamins A, D, E and K); and water-soluble (vitamins B's and vitamin C). Vitamins are organic compounds, each with a unique chemical composition (Brown, 2018). Yellow maize contains many essential vitamins, with the exception of vitamin B_{12}. Vitamin A, as carotenoids, and vitamin E, like tocopherols, are the fat-soluble vitamins in maize kernels. Vitamins A and E are important antioxidants, among their other functions (Nuss and Tanumihardjo, 2010). For yellow maize varieties, about 60% of provitamin A carotenoids are in the form of *β*-carotene (0.97 *µ*g/g), followed by *α*-carotene (0.63 *µ*g/g) and *β*-cryptoxanthin (<0.01 *µ*g/g) (Haytowitz *et al.*, 2011). Only three provitamin A carotenoids, that is, *β*-carotene, *α*-carotene and *β*-cryptoxanthin, contribute to vitamin A needs, if eaten in sufficient quantities (Johnson, 2004). When comparing yellow maize to white maize, yellow varieties can be assumed to have superior provitamin A content, because carotenoids are generally absent in white cultivars. Many populations chronically suffer from vitamin A deficiency (VAD), but still maintain cultural preferences for the consumption of white maize varieties (Pixley, 2013).

Iron, zinc, and protein deficiencies and infections can further impair an individual's vitamin A metabolism and status (Field, Johnson, and Schley, 2002). Total kernel vitamin E ranges from 0.3 to 0.7 mg/100 g. Vitamin E is found almost exclusively in maize germ oil; refined corn oil contains high concentrations of vitamin E (14.8 mg/100 g) (Schwartz, 2008). Water-soluble vitamins are found in the endosperm and germ. Kernel endosperm contains 80% niacin (vitamin B_3), 4% in the seed coat and 2% in the germ. Unless properly processed, maize niacin is biologically unavailable to humans and long-term consumption of improperly prepared maize can lead to pellagra (Kies, Kan and Fox, 1984). Pellagra is a disorder due to the inadequate dietary intake of niacin and/or tryptophan, manifested by characteristic dermatitis on areas of the skin that are exposed to the sun, beginning as erythema with pruritus that may lead to vesiculation, but more frequently becomes chronic, rough, scaly and complex, with the formation of crusts as the result of haemorrhage. The digestive tract and nervous system may be affected, resulting in diarrhoea, with profuse watery and sometimes bloody stools, anxiety, depression, tremor and reduced or absent tendon reflexes; encephalopathy may occur in severe cases. The disease is classically associated with a diet based on non-alkali-treated maize (WHO, 2000). Cooking maize with lime and heat can hydrolyse niacin through the process of nixtamalization. According to GrainSA (2019), this process converted the hard kernels into a more digestible form and released the bound niacin. Without this process, there would have been much higher incidences of pellagra, due to niacin deficiency. In Europe, North America and Africa, where the nixtamalization process was not used, pellagra became a problem in some areas. Adding the fortification of maize products with niacin, in 1941, contributed to eliminating pellagra as a significant health problem in the Southeastern United States. Pellagra was not a public health problem in other parts of the world, perhaps because they had a more varied diet that provided sufficient niacin (Rajakumar, 2000).

II. Minerals

Environmental factors, such as soil quality, substantially impact kernel mineral content. The germ contains nearly 80% of the kernel's minerals and the endosperm has less than 1%. Phosphorus, potassium and magnesium are the most prevalent minerals found in maize, providing nearly 85% of kernel mineral content. The fourth most abundant element is sulfur, primarily present in an organic form, as a constituent of methionine and cysteine (Kaul, Jain and Olakh, 2019). Zinc levels average 20 μg/g, 30% of which resides in the kernel endosperm. Total calcium and iron levels are negligible, and the concentrated germ phosphorus levels retard the bioavailability of these minerals. Other trace minerals include manganese, copper, selenium and iodine (Nuss and Tanumihardjo, 2010).

2.3 MAIZE BY-PRODUCTS

Maize can be used in various industries to produce food and industrial products, including starch, sweeteners, oil, beverages, glue and industrial alcohol (GrainSA, 2020). A summary of the different by-products developed and used in multiple industries is described below.

2.3.1 Animal feed

I. Corn gluten meal

Gluten meal is a by-product of the wet milling of corn (maize) and corn starch production. Additionally, it is also a by-product of alcohol extraction in the wine-making industry (Jiang *et al*., 2020). Corn gluten meal is essentially extracted from the endosperm of the maize kernel, consisting mainly of zein (prolamin) and glutelin (eCFR, 2023). Although it is called corn gluten meal, it does not contain gluten. Gluten meal is a protein-rich feed that contains about 65% crude protein. It is an important source of protein, energy and pigments for livestock species, such as fish. This by-product is valued in pet food, for its high protein digestibility (Nordfeed, 2016).

Nordfeed (2016) further noted that the product is golden yellow in colour and has a fine granular texture (Figure 2.3). Corn gluten meal is mainly used as a source of protein, as a potential alternative to other plant-based proteins or animal proteins, such as soybean meal or bone meal.

Figure 2.3: Maize gluten meal (Nordfeed, 2016).

II. Maize fibre

Fibre, the cellulosic portion of the maize grain, is rich in carbohydrates that are easily digestible by farm animals, such as cattle (Figure 2.4) (GrainSA, 2020). Corn fibre is a byproduct of the corn wet-milling industry and a significant amount of it is produced in corn-producing countries, like South Africa (Hespell, 1998). Cattle breeding and the production of oil cakes are two industries that make use of it.

Figure 2.4: Cattle feeding on maize fibre (Maize Suppliers, 2021).

III. Oil cake

Corn oil cake is the residue left after extracting oil from dry maize germs. It is a major ingredient in the cattle feed industry (Figure 2.5), due to its high fat and protein content (GrainSA, 2020).

Figure 2.5: Maize oil cake (RK Foods, 2019).

2.3.2 Food industry

I. High maltose maize syrup

GrainSA (2020) explains that high maltose maize syrup is a food additive that serves as both a sweetener and a preservative. It is often used to manufacture ice creams, confectioneries and baked goods.

II. Oil

The oil is obtained from the maize germ (Figure 2.6). It is a cooking medium in the food industry and in many consumer households (GrainSA, 2020). Its primary application is in cooking, where its high smoke point makes corn oil an excellent frying oil. It's also a vital component of some margarines. Corn oil is generally less expensive than other vegetable oils (Ariyan International Inc, 2021).

Figure 2.6: Maize oil (Ariyan International Inc, 2021).

III. Liquid glucose (corn syrup)

Corn syrup and glucose syrup are synonyms, and are typically produced by heating starch in the presence of an acid. It is used to produce food products, such as jam, jellies, chewing gum and canned fruits (GrainSA, 2020).

IV. Special maize starch

The starch is derived from the kernel's endosperm. It's commonly used to thicken sauces and soups, and corn syrup and other sugars (Figure 2.7) (GrainSA, 2020).

Figure 2.7: Corn starch (Shoprite, 2021).

V. Dextrose monohydrate

GrainSA (2020) identified dextrose monohydrate as a white crystalline powdered sugar, obtained by hydrolysing maize starch. It is used in confectionery, bakery, snacks, beverages and dairy products, as a sweetener, a fermentation substrate and wetting agent.

2.3.3 Textile and paper industry

I. Sayatex

Sayatex is a maize-derived oxidised starch. It is granular and white in colour, and has a moisture content of 12 to 14%. Sayatex is a film that is highly adherent, continuous and clear. As a surface sizing agent, it improves the bonding of loosely attached fibres in paper and yarn (GrainSA, 2020; Maize Products, n.d.).

II. Native maize starch

Native maize starch is a cereal starch with low mineral and protein content. It is used in the textile finishing process, to change the fabric's stiffness, feel or handle; thus, changing the appearance of the fabric by filling the weave interstices and adding weight (GrainSA, 2020).

III. Dextrins

Dextrins are the by-product generated through the process of starch hydrolysis, known as dextrinization. This process involves the breakdown of amylose and amylopectin into smaller and sweeter-tasting molecules, facilitated by the application of heat (Brown, 2018). According to Loto and Loto (2013), a dextrin is also commonly referred to as a soluble gummy substance, formed from starch by heat, acids or fermentation. Additionally, it is known for its thickening and adhesiveness, which is commonly used in glue products (Group, 2014; Loto and Loto, 2013). GrainSA (2020) further notes that industries, such as textiles and detergents, frequently employ its usage (GrainSA, 2020).

IV. Sayafied

Sayafied is used in the paper, dry wall and textile sizing industries (GrainSA, 2020). Esterified starch is used to protect gypsum crystals that form the bond between the gypsum core and the paper, during the manufacturing process of a gypsum wallboard (Figure 2.8).

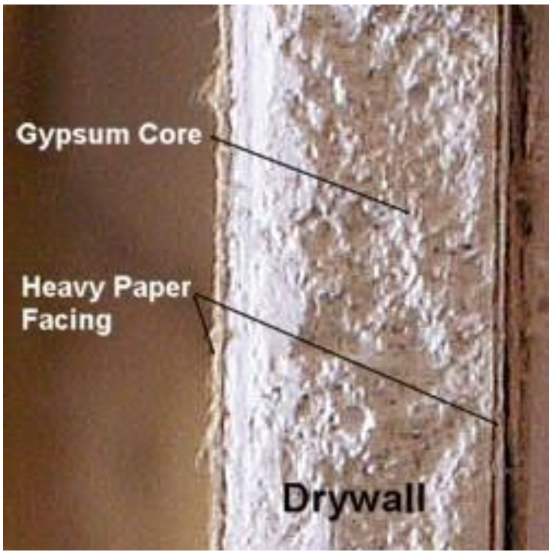

Figure 2.8: Gypsum core board (Made-In-China, n.d.).

2.3.4 Pharmaceutical industry

I. Dextrose anhydrous

Dextrose anhydrous is a substance that is used in intravenous injections (Figure 2.9), to prevent dehydration (GrainSA, 2020).

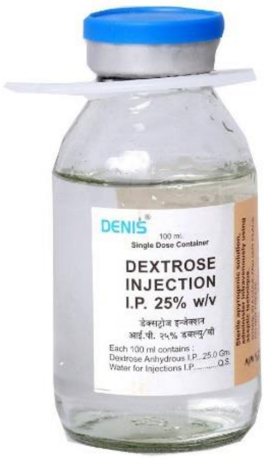

Figure 2.9: Dextrose anhydrous intravenous injection (Indiamart, n.d.).

II. Starch ip/bp

Starch ip/bp is a pharmaceutical-grade starch. The primary application of corn starch in a pharmaceutical formulation is as a binder and filler for tablets and capsules (GrainSA, 2020).

III. Maize steep liquor

Maize steep liquor, or CSL, is a by-product of wet maize milling. It contains a significant amount of soluble protein, carbohydrates and minerals, found in maize. GrainSA (2020) further signifies that it plays an important role in manufacturing of penicillin and other antibiotics.

2.4 MAIZE IN SOUTH AFRICA

South Africa is well-known for its reputable maize, which is essential to commercial and subsistence farming communities. Additionally, it is the country's most produced crop (FAO, 2022). Approximately eight million tons of maize grain are produced annually in South Africa, with the Free State, North West, Mpumalanga and KwaZulu-Natal being the major maize-producing provinces in the country. Collectively, these provinces account for about 83% of the total national production of maize (Adisa *et al.*, 2019). Maize, a vital grain crop in South Africa, is grown under diverse climatic conditions, throughout the country. It serves as a staple for the majority of the population and is a significant component in animal feed (Adisa *et al.*, 2019). Furthermore, the significance of maize in the food industry cannot be understated, as a large proportion of the population consumes this staple, therefore contributing to food security. Maize and maize-based products are consumed by approximately 67% to 83% of the population. On average, the daily consumption averages between 476 g to 690 g per person (GrainSA, 2017).

In the context of developing countries, particularly the Sub-Saharan Africa (SSA) region, and specifically in South Africa, diets often consist of an unbalanced supply of essential nutrients required for overall well-being (Goredema-Matongera *et al.*, 2021). Most people from this region often consume cereals, such as maize and cassava, as their staple foods (Maziya-Dixon *et al*., 2000). In particular, maize is very high in carbohydrates, but lacks several essential amino acids, including tryptophan and lysine (Nuss and Tanumihardjo, 2010). Furthermore, the reliance on maize can contribute to the onset of health conditions related to nutrient deficiencies, such as pellagra (Nuss and Tanumihardjo, 2011). This form of malnutrition is also observed, although less frequently, in developed countries, which could be attributed to advanced economies of developed countries, which allow individuals to diversify their diets, with an array of highly nutritious foods (Hefferon, 2015). Onyango (2003) notes that a diversified diet is a contributing indicator of food security and a predictor of nutritional status.

Nevertheless, the consumption of a consistently diversified diet in Africa poses a challenge, as most African populations consume monotonous starchy staples, coupled with limited intake of animal products, fruit and vegetables (WHO, 1998). Goredema-Matongera *et al.* (2021) noted that a diversified diet consists of protein sources, such as beans, peas, fish, meat and milk, as well as fruits and vegetables, which are abundant in vitamins and minerals, along with carbohydrates from cereals, which can effectively mitigate the challenges associated with malnutrition. The statement made by the aforementioned authors aligns with the findings of Bouis (2003), as it emphasizes that addressing malnutrition lies in the consumption of non-staple foods, particularly animal products, which are abundant in bioavailable micronutrients. However, due to financial constraints, many households in developing countries are unable to consume a nutritionally balanced diet (Bouis, 2003). Given the difficulties in achieving a diversified diet among most populations in developing countries, mandatory food fortification has been implemented by countries, such as South Africa, Zimbabwe, Nigeria, Malawi, Uganda and Kenya. These countries fortify basic commodities, such as salt, bread, maize meal, wheat flour and infant formulas with a range of vitamins and minerals (Gomo *et al.*, 1999). However, food fortification presents its own set of limitations, such as mineral toxicity, due to inefficient monitoring systems by processors (Maqbool and Beshir, 2019; Hess and Brown, 2009). In addition, extra costs are incurred by the processor, which are included in the price of the final product (Lalani, Bechoff and Bennet, 2019). Therefore, fortified foods are more costly than unfortified foods. Furthermore, relying on fortified foods, to address nutrient deficiencies, has limited coverage in rural areas, as the majority of rural populations depend on home-based food products that are not fortified (Bégin, Cervinskas and Mannar, 2001).

Furthermore, alternative approaches include combining maize varieties with other complementary foods that are rich in essential nutrients. For example, Beswa *et al*. (2016) conducted a study where they incorporated amaranth into maize-based snacks. Cardoso *et al*. (2009) reported that green leafy vegetables, such as amaranth are well known for its high levels of provitamin A and mineral contents. Beswa *et al*. (2016) aimed to assess the provitamin A content in the combined formulation. Their findings indicated that increasing the ratio of amaranth to maize led to a significant increase in both provitamin A and phenolic content. Another notable example can be seen in the study by Olusanya *et al.* (2020), where *Moringa oleifera* leaf powder was added to mahewu, a fermented maize-based beverage. The reason behind incorporating moringa was that mahewu lacks in lysine and tryptophan, while moringa is dense in many essential nutrients (Saini, Sivanesan, and Keum, 2016; Blandino *et al*., 2003). The findings of Olusanya *et al*. (2020) revealed that the addition of moringa leaf powder to mahewu significantly increased its nutrient content, such as protein. Evidently, incorporating nutrient-dense foods with maize has the potential to enhance its nutritional value, therefore improving the overall nutritional quality.

The preceding paragraphs provide a comprehensive overview of maize's importance in food security and its contribution to nutrition insecurity. It highlights that, while maize serves as a staple food for many impoverished communities, it also presents challenges, due to its inadequate supply of essential nutrients, resulting in an imbalanced diet.

2.4.1 Food security

Food security is defined as a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences, for an active and healthy life (FAO, 2006). Therefore, household food security exists when food is available, accessible and affordable to households (Coutsoudis, 2000). Furthermore, food insecurity is also an important factor, when discussing food security. The National Research Council (2006) highlights that food insecurity can be measured in three ways: (i) the uncertainty about the availability and accessibility of food in the near future; (ii) an insufficient amount and the kind of food available for the promotion of a healthy lifestyle; and (iii) the need to use socially unacceptable ways to acquire foods.

The FAO divides the idea of food security into a set of distinct, but interrelated constituent dimensions: the four-pillars model. The four pillars or dimensions include food availability, access to food, stability and utilisation. Firstly, *food availability* outlines the availability of food in sufficient and appropriate quantities and quality. Foods can be made available through domestic production, imports, donations and food aid. Secondly, *food access* refers to individuals' or households' ability to purchase or produce foods for their needs, in sufficient quantities. Thirdly, *stability* addresses the risks that can negatively impact food availability and accessibility. These risks could include economic and climate crises. Lastly, *utilisation* refers to food preparation, processing and cooking. It also refers to people's ability to absorb the nutrients from food (Alonso, Cockx and Swinnen, 2018; Gibson, 2012). The four pillars highlight the multi-dimensional aspect of food security and how interdependent each pillar or framework relies on the other.

Moreover, the inequality faced by South African citizens, due to the Apartheid regime, has resulted in high levels of unemployment and poverty among non-white South Africans. These adverse conditions persisted throughout the duration of the regime, from its inception to its eventual dismantling (Leibbrandt, Woolard and Woolard, 2009). It was revealed by Altman and Ngandu (2010) that the high prevalence of unemployment, low wage levels among most South Africans and the high cost of living are major contributors to household food insecurity. According to StatsSA (2019), approximately 20% of South African households had inadequate access to food in 2017. Furthermore, it was revealed that black and coloured households are more disadvantaged when accessing adequate amounts of food, than white households. Additionally, the size of a household directly influences food security, as it does on food insecurity. Thus, larger households are more at risk for food insecurity, as it has been reported that households with three or more children were more likely to experience inadequate access to sufficient food (StatsSA, 2019).

It is generally believed that South Africa is food secure, either because its agriculture produces sufficient staple foods or because it can import nutritional food (Masipa, 2017). However, it has been reported that the country is food secure at national level, but not at household level (Hart, 2009). Rising food prices significantly impact household food security in the country (Gulati *et al.*, 2013). Masuku, Selepe, and Ngcobo (2017) further note that socio-economic attributes, such as education, gender, age and marital status significantly influence food accessibility for lower-income households. It was revealed that during the Covid19 pandemic, lower-educated households' food security was the most affected than those with secondary or tertiary education (Arndt *et al.*, 2020). Further, Arndt *et al.* (2020) highlighted that low-educated households, relying on labour income, were more vulnerable and more susceptible to food insecurity, due to job and salary cuts. This is especially true for rural households that have limited income-generating opportunities. (StatsSA, 2011).

I. Addressing food insecurity through training and income generating activities

For households to be food secure, they need consistent access to adequate amounts of food (HSRC, 2013). However, individuals need access to income to purchase food for themselves and their families (Ngema, Sibanda and Musemwa, 2018). Due to the high unemployment rate and lack of skills amongst most of the poor, income-generating workshops were established to address poverty-related issues, in the form of training.

Income generation serves as a mechanism to decrease food insecurity among the unemployed through income-generating activities, where households can mitigate food insecurity, unemployment and lack of economic opportunities (Nkoko, 2020). Community-based income-generating projects are some of the strategies used by the South African government, to reduce poverty (Mayer *et al.*, 2011). Providing immediate cash inflow, income-generating community projects facilitate skill development among participants (Oldewage-Theron and Slabbert, 2010). It was determined by Hortensia (2009), that income-generating projects allow the participants to pay for immediate needs, improve the health and nutritional status of themselves and other household members, and improved their skill level. Training programmes are being implemented to address the lack of skills and knowledge in agricultural and agro-processing fields. According to Mutanana and Gasva (2015), income-generating projects for women contribute significantly to improving their standard of living. In addition, the projects contribute to the mobilization of essential resources, such as untapped skills, talents, leadership qualities, human energy and other resources (Zikhali and Zikhali, 2017). One example is that of GrainSA (2021), where training is provided to rural women and smallholder farmers, about the process and benefits of nixtamalization. During the contact sessions, mentors educated and advised farmers on harvesting, storing and marketing the crop. Another example is the development of recipe and products by the University of the Free State (UFS) that could be easily produced and sold by women from lower-income communities (Staff Reporter, 2022).

According to Niesing (2012), female participants usually make up most of those who participate in income-generating projects. Furthermore, Lemke, Bellows and Heumann (2009) found that female-headed households are more food secure, as they play an imperative role in the family structure. They are also often responsible for making food consumption decisions in most households (Appelhans *et al.*, 2019). In addition, they are primarily concerned with raising children and are more nutritionally vulnerable when pregnant or nursing. Moreover, children's dependency on adults for their growth and nutrition makes them highly vulnerable. The risk of mental development, stunting or chronic malnutrition for children, under two years of age, is exceptionally high when poor foetal growth is combined with poor nutrition, in their first 24 months of life. This is particularly important, when the infants are weaned off breastmilk, to the introduction of solid foods. There is a strong correlation between poverty, undernutrition and food security (Gibson, 2016).

According to the preceding discussions, regarding maize and its impact in South Africa, the focus shifts towards the introduction of nixtamalization, as a cost-effective processing technique, with the potential of addressing maize-related challenges, which can mitigate the issues mentioned above.

2.5 NIXTAMALIZATION

Maize foods are characterised by their distinctive flavour, which cannot be duplicated by any other cereal grain. Processed maize is manufactured from raw materials obtained through dry milling, wet milling or nixtamalization (Serna-Saldivar, 2016). For this literature review, the primary focus will be on nixtamalization. The nixtamalization process is a multi-step technique, commonly employed in Mexico, Central America as well as the southern regions of the United States, to transform maize into tortillas and fried snacks (Fernández-Muñoz *et al.*, 2004). Firstly, the grains are cooked in an aqueous-alkaline solution of $Ca(OH)_2$, commonly called lime. Thereafter, the kernels are steeped for 12 hours or overnight, causing the surface starch of the endosperm to gelatinise (Rojas-Molina *et al.*, 2007). After steeping the kernels, the solution is drained, and the kernels are rinsed to remove excess lime and pericarp residues, transforming maize into nixtamal. The following step involves the thermo-mechanical process of wet milling, in which the nixtamal is milled wet, to produce a dough called masa. The masa is then moulded into a tortilla, and the third and final step takes place, the cooking known as the thermal process (Villada *et al.*, 2017). In addition, the production of nixtamalized maize flour is also attainable by drying the nixtamal or masa in a convection oven, followed by milling and sieving, to yield flour (Adeloye, Osho and Idris, 2020). Moreover, the nixtamalization process alters the physicochemical, nutritional and sensory properties of maize products, by increasing the content of calcium, magnesium and potassium, and reducing fumonisin levels and the quality of protein (Ramírez-Vega *et al*., 2022).

Since Mexican foods have gained popularity in the United States and around the world, alkaline cooking or nixtamalization of maize has become necessary (Serna-Saldivar, 2016). According to Elpaso Mexican Restaurants (2021), the American fascination with Mexican food started primarily due to the Mexican Revolution. At that time, many Mexican refugees fled their war-torn civil country and sought a home in the United States. In America, many immigrants continued to cook and serve local dishes to their families, to preserve their cultural practices. Their attempt to make a decent living in a foreign country resulted in them selling tortillas and other Mexican food. In the 1920s, many small Mexican restaurants were established in Texas and Southern California. Several factors contributed to the popularity of Mexican food among Americans, including business, immigration and widespread popularity. Although many Americans eat popular versions of Mexican food, far removed from their Mexican origins, they make up a large portion of their diets. Culinary staples, like tortillas, salsa, chips, chilli, burritos and tacos helped cement many Americans' notions of Mexican food (Arellano, 2012).

2.6 TRADITIONAL AND ALTERNATIVE NIXTAMALIZATION TECHNOLOGIES

The traditional nixtamalization process, and the effects on tortillas' chemical and nutritional properties, have been widely studied over the last decades. However, there are new food production technologies that give more significance to health and environmental issues, and the industry's economic interests. Besides traditional nixtamalization, several alternative processes have been reported (Ramírez-Araujo, Gaytán-Martínez and Reyes-Vega, 2019). Ramírez-Araujo, Gaytán-Martínez and Reyes-Vega (2019) explained that the application of these technologies induces several different molecular effects in the grain's components that change the chemical, nutritional and functional properties, of the produced tortillas and products. Needless to say, the effects could be auspicious, but also unfavourable, affecting the consumers' health and the manufacturing industry. Although food scientists have developed several nixtamalization methods (ecological, time-saving, and enhanced nutritional and nutraceutical properties), industrialists have not embraced these methods, because they fear the impact on their business profits (Escalante-Aburto *et al.*, 2020).

2.6.1 Traditional nixtamalization technologies

I. Classic nixtamalization

Volcanic or wood ashes were used for the classic nixtamalization of maize grains. The process involved cooking maize with water and volcanic/wood ashes, resulting in by-products, such as nixtamal, masa, flours and tortillas, with different profiles, regarding mineral content, dietary fibre and resistant starch. According to archaeological evidence, in the beginning, this method was used by the Mayas (wood ashes) and then the Aztecs substituted ashes with lime (Mariscal Moreno, 2015). Reports indicate that classic nixtamalization was developed before traditional nixtamalization. The substitution of wood ashes, with lime, was based on the higher pericarp removal. Lime removed the seed coat of maize kernels more efficiently and provided a softer texture for the masa and tortillas. Masa (corn dough) is kneaded, rolled into balls, pressed flat and cooked into tortillas on a plate made of clay, called "comal", which is held over the fire by stones. After constant exposure to heat, the "comal" slowly produced $Ca(OH)_2$. The ancient populations experimented with this substance, which led to the use of lime and its substitution for ashes (Bressani, 1990). The removal of pericarp by classic nixtamalization is more delayed, when compared with other methods. Classic nixtamalization, therefore, increases the processing time, wastes high amounts of water and creates polluted residues (Escalante-Aburto *et al.*, 2020).

II. Traditional nixtamalization

The use of alkali treatment to soften the outer kernel is still a common practice on the American continent, by those that cultivate and consume large amounts of maize (Escalante-Aburto *et al.*, 2020). The traditional nixtamalization process was a well-known process, developed and used from the Aztec era, 1325 A.D. How this process came to be, is still unknown (Bressani, 1990). Escalante-Aburto *et al.* (2020) emphasize that the crossover to lime, instead of wood ashes, had a technological purpose: to reduce the time spent processing, since lime more efficiently removed the grain pericarp. The process involves the addition of lime, to achieve corn grain dehulling, and to obtain masa and its several by-products (Santiago-Ramos *et al.*, 2018; Bressani, 1990). This process has countless advantages from a technological point of view, such as better rheological properties, viscoelasticity and sensory characteristics (Santiago-Ramos, de Dios Figueroa-Cárdenas, and Véles-Medina, 2018). According to Escalante-Aburto *et al.* (2020), it is imperative to note some nutritional and microbiological improvements that are widely known, such as the release of bound niacin, an increase in protein quality, an increase in calcium content, and reduction of mycotoxin concentration, among others. However, the disadvantages of the traditional nixtamalization process are a reduction of nutraceutical compounds, a reduction of dietary fibre content and a total fat decrease (Serna-Saldivar, 2016; Wacher, 2003). The main disadvantages are high nutrient and phytochemical loss, long steeping times and the production of high amounts of nejayote, with a high pH of around 9 to 12, which holds polluting residues. This residue also has high biological and chemical oxygen demand values (2 500 mg/L), an elevated biological oxygen demand (8 100 mg/L) and suspended solids of 20 000 mg/L, and it is regularly discharged into public drainage (Jackson and Sahai, 2002). Due to the disadvantages as mentioned above, there is a need to improve the process to make traditional nixtamalization more sustainable with additional nutritional and sensorial benefits (Escalante-Aburto *et al.*, 2020).

2.6.2 Alternative nixtamalization technologies

The following section presents a description of some of the technological developments, of the alternative nixtamalization methods.

I. Ecological nixtamalization

To reduce the contamination, provoked by nejayote production (a solution with high polluting residues), ecological nixtamalization was proposed and patented by Figueroa *et al* (2011). Escalante-Aburto *et al.* (2020) described that the use of water is not reduced; however, the pH of the residue solution is around 4.19 to 7.38, which is significantly lower than that obtained from traditional nixtamalization, which can be from pH 12 to 14. These differences in pH values depend on the calcium source; in this process, the additive that produced the most significant pH reduction was calcium sulfate. Calcium salts, such as sulfate, carbonate and chloride, were used to achieve an incomplete grain-dehulling of the pericarp, resulting in a product with a higher content of dietary fiber, with lower production of polluting substances.

Ecological nixtamalization improves the retention of nutraceutical compounds, when pigmented maize genotypes are used (Méndez *et al.*, 2013). Moreover, some nutritional properties reported are high protein efficiency, thus, suggesting nutritional improvement in the ecological nixtamalized products. Nixtamalized products, produced through ecological nixtamalization, showed good appearance and excellent sensory characteristics, compared to those produced by traditional nixtamalization (Mariscal-Moreno *et al.*, 2017; Maya-Cortés *et al.*, 2010).

Escalante-Aburto *et al.* (2020) reiterate that the pH reduction in the water waste solution, seemingly diminished the ecological impact, as a principle technological advantage. Nonetheless, the use of large amounts of water is not considered a feasible solution for the large-scale production of tortillas and nixtamalized products. A better nutritional profile in the products is achieved, which counteracts the ecological detriments, which could have a remarkable positive impact on public health.

II. Nixtamalization by extrusion

Nixtamalization by extrusion has some reported advantages over the traditional process, such as considerable water consumption reduction, contaminating residues (no nejayote production), aflatoxin content, processing time and equipment necessities. In this high temperature-short time (HTST) process, corn grains are milled to obtain different particle sizes, depending on the product and then mixed with $Ca(OH)_2$, and conditioned at different moisture contents (14 to 45%) (Brennan *et al.*, 2011). The milled corn is then allowed to rest for a period of time (up to 12 hours at room or refrigeration temperatures) in sealed containers, to better hydrate the starch particles and the interaction with calcium sources. After resting, the mix, known as *conditioned flour* (ground corn + additive + water), is put into the feed hopper and passed through the extruder. The extruder has a screw inside the barrel, and the material flows into the different heating and cooling zones, and the conditions (temperature of the zones, screw velocity, screw type) are set according to the desired product. Finally, the cooked sample comes out through the die (which has different forms and diameters) and the obtained materials (pellets) are milled again, to obtain nixtamalized extruded flours. These flours are then hydrated to form masa and flattened into tortillas, to be cooked and consumed. The texture properties of tortillas, obtained with this technology, are not satisfactory and not highly accepted by consumers, due to the high fragmentation of starch molecules, by the high pressure inside the barrel and high shear rate, causing extensive retrogradation of amylose chains, giving, as a result, stiff products (Platt-Lucero *et al.*, 2013). The ecological advantage of the nixtamalization by the extrusion process is that the water usage is reduced, up to 90 to 95%, when compared with classic, ecological and traditional nixtamalization. Energy consumption remains the same as classic, ecological and traditional nixtamalization, since using two principal types of equipment is necessary to obtain masa (mill and extruder). It is possible that the experimental use of screws, with different characteristics, to avoid or reduce starch damage in the corn flours, can be developed, because the negative effects on the starch granules destroy the textural properties of tortillas. This is why nixtamalization by extrusion is used, basically to produce nixtamalized snacks instead of flours and tortillas; however, this process is more versatile, due to the multiple functional extruders (Escalante-Aburto *et al.*, 2020).

III. Nixtamalization using ohmic heating

Ohmic heating is an alternative process used as a continuous in-line heater, for cooking and sterilising of viscous liquids and mixtures, containing particulate food products. This process comprises the internal generation of heat, by passing an alternating electric current (AC) through the food, which acts as a resistance. The principles of this method are simple; an electric AC current is applied to electrodes, surrounding the food matrix or medium. The continuous ohmic heater is fed with a mix of ground corn, previously conditioned with water and lime. An internal generation of heat cooks the material, resulting in a paste (masa) that is dried and milled, to obtain nixtamalized flour, with different particle sizes (Ménera-López, 2013).

Escalante-Aburto *et al.* (2020) highlights that the most important factors to be controlled, before and during the process are the particle size of the corn grains, the concentration of water and lime added to condition the flours, process temperature, and the applied voltage or electric power. Once the cooked material is obtained, other factors need to be considered, such as the type of dryer and mill, which depends on the final use of the flour.

The main advantages of this technique are a reduction in processing time and nejayote production. Ohmic heating is similar to nixtamalization by extrusion, since a mill and specific equipment, in this case, an in-line heater, are required to obtain masa and nixtamalized products. As a result, reduction of microorganisms (since sterilization takes place) in the final product can be achieved, and since whole kernels are used, the nutritional properties are improved. The production of instant masa is an additional benefit (Escalante-Aburto *et al.*, 2020). Nutritional characteristics showed higher protein and dietary fibre content, concluding that the continuous ohmic heating process is effective and a new alternative to obtaining similar nixtamalized products, to those of traditional nixtamalization (Gaytán-Martínez *et al.*, 2012).

IV. Nixtamalization using infrared heating (NIH)

Infrared heating involves exposing a material to electromagnetic radiation, at a wavelength of 1.8 to 3.4 µm. Penetration of these waves or infrared rays, into biological materials, causes vibration of water molecules, at a frequency of 60,000 to 150,000 MHz, and thus, rapid internal heating and water evaporation from the material are achieved (Fasina *et al.*, 2001). Vázquez-Durán and Moreno-Martínez (2014) reported that infrared nixtamalization retained 25.1 - 32.7% more lipids and up to 41.5 - 72.3% more tryptophan, than traditional nixtamalization. Another important fact is that tortillas manufactured by NIH showed the lowest value of starch retrogradation. The main disadvantages are that there is no reduction in water use, contaminant effluents and processing time.

Vázquez-Durán and Moreno-Martínez (2014) further concluded that nixtamalization, using infrared heating, resulted in improved nutritional and rheological characteristics of tortillas. The NIH process has shown multiple advantages compared to other traditional methods, such as classic and traditional nixtamalization. However, it is similar to other dry nixtamalization technologies, like nixtamalization by extrusion regarding energy efficiency, reduction of heating time, temperature uniformity on the material and reduction of nutrient losses.

More water (3 litres per kilogram of nixtamal) is used to wash the cooked grains, which increases water wastage. An important issue of NIH technology is the reduction of aflatoxin content in tortillas, which is an excellent benefit of this method (Zavala-Franco *et al.*, 2016).

V. Nixtamalization by fractionation

Nixtamalization by fractionation is based on the separation of two fractions: one being the pericarp, germ and tip cap, and the other being the endosperm. Maize grains are steeped in water to facilitate the separation of the anatomical parts, using a decorticator. A pneumatic separator divides the first fraction by density. Both fractions are nixtamalized separately, at different lime concentrations and times. Finally, nixtamalized flours are obtained after drying and milling of both fractions (Cortés-Gómez *et al.*, 2005). Escalante-Aburto *et al.* (2020) pointed out that the process of nixtamalization of two fractions resulted in a longer processing time, since the maize kernel needed to be dissected. This complicated the nixtamalization process, resulting in a more labourious process. Cortés-Gómez *et al.* (2005) noted that there is a reduction of water and lime, but these reductions are insufficient to compensate for the required processing time, to achieve a final profitable product, even when nutritional properties are preserved.

VI. Selected nixtamalization

Selected nixtamalization is a process developed by Martinez-Montes *et al.* (2001). It is described as separating kernels into three fractions, which is milled and then each fraction is subjected to different treatments. The pericarp fraction is conditioned with an alkaline solution and cooked. The endosperm-germ fractions are conditioned with water in sufficient amounts, to achieve the desired hydration of the particles. Ultimately, all the fractions are cooked. This process proposes several options to perform the cooking step, such as: extruder; infrared heating; microwave oven; joule cooking chamber; pressurizing chamber; and cooking containers.

The claimed advantages of this process, are the high nutrient quality of the byproducts, due to the use of whole grains and the preservation of the rheological characteristics and other physicochemical properties of masa, instant corn flour and tortillas. In addition, steeping times are shorter than those in the traditional process. However, the pretreatment of the corn grains (separation of the anatomic parts) and milling require extra equipment and time, making this process more laborious and complex. On the other hand, the detailed cooking process of each corn fraction produced excellent nutritional properties (Martinez-Montes *et al.*, 2001).

VII. Enzymatic nixtamalization

The development of the enzymatic nixtamalization was carried out by Jackson and Sahai (2002), to minimise water waste, reduce the processing time and ease the recycling process. Corn grains are first hydrated at 25 to 80% and digested with an alkaline protease solution, before an alkali is added ($Ca(OH)_2$, sodium hydroxide or potassium hydroxide), increasing the pH levels and favouring the enzymatic activity.

Escalante-Aburto *et al.* (2020) explained that only partial starch gelatinisation takes place in this process. The process involves degrading the protein contained in the pericarp by the protease, softening the cell walls, thus facilitating the milling. Nonetheless, in enzymatic nixtamalization, the cooking/steeping process can take place without lime, depending on the type of corn. Usually, hard maize kernels are cooked at 90ºC for 15 minutes, before the enzymatic treatment, to obtain the desired softness and to facilitate the milling.

The main advantage of enzymatic nixtamalization is the allowance of water recycling, but procuring the enzymes could be expensive. The reduction of space requirements is not possible, since containers for enzyme digestion are necessary, as well as containers for the treatment with some alkali, to remove the pericarp. Technological and nutritive studies are needed to analyse the process's benefits (Escalante-Aburto *et al.*, 2020).

VIII. Ultrasound-assisted nixtamalization

The utilisation of ultrasound to nixtamalize has been documented, to describe the effects on the physicochemical, morphological, and structural characteristics of maize processed by this technology. Herrero and Romero De Avila (2006) explained that the process involves a solution of maize, lime and water, heated by ultrasound, employing physical and chemical changes that result in the generation and evolution of microbubbles in a liquid medium. The bubbles are produced by high or low-intensity sound waves, causing the oscillation of molecules and producing voids or cavities (cavitation), creating alternate cycles of compression and refraction that cause pressure changes and disrupt the structures (O'donnell *et al.*, 2010). The advantages include reducing processing time and solid losses in the nixtamal, obtained by traditional nixtamalization, using power ultrasound with an acoustic energy density of around 1.85 W/g (Janve *et al.*, 2013). Robles-Ozuna *et al.* (2016) evaluated the physicochemical, structural and quality characteristics of maize undergoing this process. It was found that less starch damage was observed, when nixtamalization was assisted by sonication and the cooking time was reduced up to 77.7%. The application of this technology reduced up to 30 minutes of cooking time and allowed the production of nixtamalized products, with acceptable physicochemical and textural characteristics.

However, the use of water is not reduced, since the maize to water ratio is 1:3, similar to traditional methods, while lime, in amounts up to 1.2%, are needed. Ultrasonic waves promote more efficiency during the penetration of water diffusion into the maize kernel, thus reducing the processing time and producing softer nixtamal. This consequently reduces the energy consumption when the maize is ground to obtain masa (Escalante-Aburto *et al.*, 2020).

IX. Nixtamalization by microwaves

Martínez-Bustos *et al.* (2000) studied microwave assisted nixtamalization. The nixtamal that was produced had similar characteristics to those obtained by traditional nixtamalization and other heating methods. Through this processing method, commercial nixtamalized flours can be produced more efficiently, faster and at low operating costs, and lower nejayote was produced. This process, thus, reduced the processing time. The differences in the characteristics of the flour are notably visible in this method, compared to traditional nixtamalization. These differences mainly include a reduction in the particle size, water absorption index and maximum viscosity.

The effects of calcium ion uptake through different parts of maize kernels, nixtamalized by microwave, showed that pericarp, endosperm and germ have different calcium ion diffusion kinetics. The pericarp presented the highest diffusion, since it is the component that directly reacts with the alkaline solution, causing hydrolysis. Hence, higher ion concentrations were observed in this anatomical part. In the case of the endosperm, it had the highest calcium concentration, while the germ had the lowest concentration (Escalante-Aburto *et al.*, 2020).

Escalante-Aburto *et al.* (2020) noted the major advantages of the microwave assisted process, namely that that cooking times are reduced by at least 50% and power efficiencies arise up to 70%. However, it may be important to consider the radiation effect of microwaves that could affect the chemical and nutraceutical components of the products.

X. Nixtamalization with malting and extrusion

This process is similar to nixtamalization by extrusion, but before the process is carried out, the corn grains are malted (germinated), dried, ground and conditioned. They are extruded at various processing conditions, to obtain flour and tortillas. The principal advantages are improved nutritional characteristics and no production of waste runoffs. Nonetheless, the preliminary stages (germination and drying) increase the processing time and the necessity for other equipment, such as a germination chamber, drier and mill, which requires extra space in the production plant (Rodríguez-Martínez *et al.*, 2015).

According to Platt-Lucero *et al.* (2013), better results for the physicochemical and rheological characteristics of the flour, as well as improved firmness of tortillas, were reported. This process required more equipment and space, and consequently resulted in longer processing times, perhaps, the longest time of all the processes mentioned thus far. The germination step requires a minimum of 24 hours and the conditioning of ground malted flours needs an additional 12 hours. However, the level of water wastage was reduced.

XI. Two steps nixtamalization

This process is based on the modification of traditional nixtamalization with different processing conditions, such as temperature and sources of calcium, as well as time. Two-step nixtamalization is based on ecological nixtamalization, with the use of other calcium sources than $Ca(OH)_2$, such as calcium lactate and is focused on the reduction of the pH of the nejayote (Ruiz-Gutiérrez *et al.*, 2012).

Nixtamalization was executed at a constant temperature of 80°C and two stages of 30 minutes, each. In the first stage, dented corn was cooked in a saturated solution of $Ca(OH)_2$, drained and washed. Thereafter, corn kernels were cooked for 30 minutes in a saturated solution of calcium lactate or chloride. Lastly, corn kernels were steeped for 40 hours, and a stone grinder was used to obtain masa and tortillas. The products obtained through this process showed good textural and colour properties, in comparison with commercial flour. According to Ruiz-Gutiérrez *et al.* (2012), tortillas, produced with this process, showed the most acceptable results by panellists during sensory analysis.

The major advantage of this technology is the lower pH values of the effluents produced. Even so, the process is quite complicated, since washing the nixtamal and reinitiating the cooking process, by the adjustment of calcium contents in the solutions, are tedious (Figueroa, Rodrıguez-Chong, and Véles-Medina, 2011).

XII. Nixtamalization by low shear laminar transport system

The idea emerged to replace nixtamalization with extrusion, since the high stress and shear cause high dextrinization in the starch molecules, of flours and tortillas (Ortega-Moody *et al.*, 2014). While this process is based on extrusion, the main change in the equipment is the inclusion of a transport system, with a cooking section that consists of a laminar cooker, without a die. Mercado Pedraza *et al.* (2014) briefly explained the process; pre-conditioned ground corn is emptied into the hopper (feeding section); the mix (ground corn, $Ca(OH)_2$ and water) is pumped into the cooking section; and then the material is transported in laminar flow, eliminating the turbulence, and reducing stress and shear force. The major advantages of this process are the reduction of processing time and insignificant emission of effluents. This technology reduces the energy consumption when the masa is obtained, by avoiding friction and shear force.

XIII. Nixtamalization by high-energy milling (HEM) or planetary ball milling (PBM)

The use of grinders and cookers, to produce nixtamalized flour in a continuous system, was proposed by Sterner and Zane (1984). A method and apparatus were disclosed for crushing grains under controlled conditions of humidity, temperature and impact quality. In a preferred setting, grain with added lime is fed into a grinding chamber and grounded into a fine powder, by the action of breaker bars that crush the grain against breaker plates, mounted along the circumference of a grinding chamber cage. The grain product is subjected to a steam atmosphere, generated from the grain moisture content, frictional heat and applied heat. The steam atmosphere is maintained by blocking air ingress, while feeding in grain and extracting flour and a cooked, dry flour product is obtained. Martínez-Bustos (2011) evaluated a method where, in the first process step, maize grains were milled in a hammer mill, equipped with a U.S. mesh (0.5 mm), and then the flour was conditioned at different moisture contents and $Ca(OH)_2$ concentrations. During the second stage, the conditioned flour was re-milled in a planetary ball milling that exerts higher impact energies, to grind biomass particles. As a result, different nanocrystalline and micro powders were produced by the action of moving metallic or ceramic balls, using a centrifugal force field, which changed the physicochemical, structural, rheological and functional properties of the final product (Amador-Rodríguez *et al.*, 2019; Eskin *et al.*, 2005).

Escalante-Aburto *et al.* (2020) concluded that these methods claimed a drastic reduction of processing times, from 15 to 18 hours to approximately less than 15 minutes, to prepare nixtamalized flour from whole maize kernels. HEM and PBM are the fastest methods reported to our knowledge. These processes offer the possibility of fortifying specific nutrients. Flours and products, with homogenous nutritive characteristics, could improve the well-being of patients, with non-communicable diseases (Escalante-Aburto *et al.*, 2020).

2.7 THE EFFECT OF NIXTAMALIZATION ON MYCOTOXINS AND NUTRIENTS

In the context of South Africa, where poorer communities often struggle to afford a diversified diet, the feasibility and benefits of nixtamalization, as a process for nutritional improvement, remain in question. Hence, the primary objective of this discussion will be to illuminate the nutritional advantages and challenges linked to nixtamalization, thereby assessing its potential to alleviate nutrition deficiencies, within the broader context. By addressing the challenges surrounding affordability and dietary diversification, this exploration seeks to evaluate how nixtamalization could serve as a viable solution, in mitigating nutritional deficiencies.

2.7.1 Mycotoxins

Maize is the most widely produced cereal globally, producing more than 1 billion tons annually. Regrettably, the presence of toxigenic moulds, both in the field and storage facilities, results in substantial losses of nutritional, quality and commercial value (Ponce-García, Serna-Saldivar and Garcia-Lara, 2018). Ponce-García, Serna-Saldivar and Garcia-Lara (2018) further explain that toxins may develop, due to the maize cob being covered with husks that create an optimum and protective environment for contaminating moulds. Schaarschmidt and Fauhl-Hassek (2019) describe mycotoxins as secondary fungal metabolites, produced in the field and during storage that can raise health concerns for humans and animals, due to their toxic potential. Although there are many toxic metabolites, few are known for causing disease in humans, such as aflatoxins, fumonisins, ochratoxin A, deoxynivalenol, zearalenone and ergot alkaloids, with aflatoxins and fumonisins being more detrimental to maize crops (Pitt *et al*., 2012). Pitt *et al.* (2012) further note that these toxins are primarily produced from species of *Aspergillus, Penicillium, Fusarium* and *Claviceps*.

Firstly, aflatoxins are primarily produced by *Aspergillus* and *Penicillium* species, with aflatoxin B1 (AFB1) being the most toxic and carcinogenic. Aflatoxins, including AFB1, aflatoxin B2 (AFB2), aflatoxin G1 (AFG1) and aflatoxin G2 (AFG2), are particularly common in maize and other crops produced in warmer climates, which pose a serious health threat in many counties, worldwide (Taniwaki, Pitt and Magan, 2018). Secondly, Knutsen *et al.* (2018) explain that fumonisins belong to a large group of toxins, commonly referred to as *Fusarium* toxins that are produced by numerous *Fusarium* species, such as *Fusarium verticillioidies* and some species of *Aspergillus niger.* They further note that fumonisins are frequently found in raw maize and can cause liver and kidney toxicity. Schaarschmidt and Fauhl-Hassek (2019) mention that other *Fusarium* toxins commonly present in maize, include zearalenone and trichothecenes, such as deoxynivalenol. In addition to the mycotoxins mentioned above, emerging mycotoxins have been identified that are also produced by fungi. These mycotoxins are emerging, as they are less investigated and understood. An example of such emerging mycotoxins is moniliformin (MON), which is also produced by some *Fusarium* species (Jestoi, 2008).

Mycotoxins, such as aflatoxins, zearalenone, trichothecenes and ochratoxins, are metabolites produced by fungi that can grow on maize kernels, under favourable conditions. Most of these toxins, such as aflatoxin, can be highly stable during kernel processing techniques and concentrate in the kernel fibre, gluten protein and germ (Nuss and Tanumihardjo, 2010). Approximately 4.5 billion people, in developing countries, are chronically exposed to uncontrolled aflatoxins, resulting in adverse health effects. These include impaired growth in young children, compromised nutrient utilisation of selenium, vitamins A and D, zinc, reduced immunity, infectious disease and liver carcinogenesis (Wild, 2007). Nuss and Tanumihardjo (2010) conclude that commercially grown maize is tightly regulated, using UV screening if grains are used for human consumption.

Food processing, overall, can affect mycotoxins present in the raw materials. The reduction in mycotoxin concentrations might be caused by fractionation or partial degradation of the toxins, leading to a lower toxicity level. However, lower mycotoxin levels involve modification. In such instances, the resulting structures might still harbour unknown toxicity or be converted into a toxic form (Di Domenico *et al.*, 2015).

During nixtamalization, nejayote is the main byproduct. Nejayote contains a solid fraction that mainly consists of maize tip cap, pericarp and germ, and in addition certain aflatoxins (Schaarschmidt and Fauhl-Hassek, 2019). According to a study done in Uganda by Naggayi *et al.* (2020), the nixtamalization process significantly reduced the amount of aflatoxin content in maize. In this study, nixtamalization was carried out with four maize samples, from four different districts of Uganda (Mubende, Kiryandongo, Gulu and Iganga) located in four agro-ecological zones, where aflatoxin and fumonisin contamination of maize have been previously reported. Nixtamalization was carried out on all four samples and was dried at 60°C for 16 hours, then ground into flour. Part of the flour was analysed for aflatoxin and fumonisin content, and the other was saved for nutrient and physico-chemical analysis. Results show that the nixtamalization process, using slaked lime, reduced the amount of aflatoxin content in all the maize samples. In maize samples from some districts, the reduction in aflatoxin was up to more than 90%. In a study by Schaarschmidt and Fauhl-Hassek (2019), the traditional nixtamalization process for maize reduced aflatoxin levels by 90%, while ecological nixtamalization processes reduced toxins by 92%. Research, to understand the role of slaked lime, $Ca(OH)_2$ indicated that, in addition to assisting pericarp removal, lime incorporation is responsible for the cross-linking of starch molecules, by way of the formation of a calcium bridge, with negatively charged amylose molecules (Bressani, 1990). The high pH of the alkaline processing that promotes the ionization of starch hydroxyl groups, is also responsible for the hydrolysis of the parent aflatoxin (Dombrink-Kurtzman, 2000). The study by Naggayi *et al.* (2020) further indicates that nixtamalization significantly reduced total fumonisin contamination in maize. Fumonisins are water-soluble mycotoxins, produced by the fungus *Fusarium verticillioides*, which can, therefore, filter into the liquid portion during cooking and steeping procedures (Greeff-Laubscher *et al.*, 2020; Palencia *et al.*, 2003).

2.7.2 Crude fat, sugars and crude fibre

As mentioned previously in Chapter 1, nixtamalization enhances the nutritional value of maize and maize products. The alkaline cooking of maize is believed to remove more than 95% of aflatoxins. In addition to improving the flavour of maize, some nutrients are improved and made more readily available for absorption. The amino acid tryptophan is made more readily available for absorption, which aids in preventing malnutrition. The bound niacin avails itself, directly reducing the risk of pellagra disease. The process of nixtamalization also increases the bioavailability of iron, thus, reducing the risk of developing anemia. Protein and calcium quality are also increased, as does the digestibility of maize (GrainSA, 2019).

This thermal-alkaline process produces essential changes in the morphology and rheological characteristics of starch, the significant component of maize. The cooking of maize grains in an alkaline solution of $Ca(OH)_2$, known as nixtamalization, is perhaps the most crucial process for human consumption of this cereal, since nixtamalized products, such as tamales and tortillas, are widely consumed in Mexico and by Mexican people, living in the United States (Méndez-Montealvo, 2008). The relatively high temperature during the cooking of the grain (between 85 °C and 100 °C) and the pH value (>12), facilitate diverse transformations of the grain components. Among these is the degradation of the pericarp, the loss of soluble proteins (mainly albumin and globulin) and the partial gelatinisation of starch. After cooking, the nixtamalized kernels (*nixtamal)* are rinsed with water, to eliminate the lime and ground, to produce a paste called masa (Briones *et al.,* 2000). During the grinding, additional gelatinisation of starch is carried out and other transformations in grain components are produced, since the masa is a mixture consisting of starch polymers (amylose and amylopectin), mixed with partially gelatinised starch and intact granules, endosperm parts, and lipids. All these components form a heterogeneous and complex matrix (Méndez-Montealvo, 2008).

The study by Naggayi *et al.* (2020) further indicates a 10 to 12% decrease in dietary fibre. The nixtamalization process aids in removing the pericarp. Therefore, insoluble dietary fibre decreases from raw to nixtamalized maize. However, the relatively high dietary fibre levels in the maize are of nutritional significance (Wacher, 2003). The nixtamalization process significantly reduces crude fat, total sugars and crude fibre in maize.

Naggayi *et al.* (2020) further noted that nixtamalization also significantly reduced the amount of total sugar content in maize, from 28.8 to 22.2%, which possibly was due to retrogradation and high pH of 7.1 and 7.2 (Garcia-Diaz, 2016). Maize products, with a low caloric content and a high resistant starch value, help to maintain a healthy intestine. The crude fat content of maize decreases, as the kernel is nixtamalized; this is the result of the loss of the seed coat, tip cap and possibly part of the germ (Garcia-Diaz, 2016).

2.7.3 Protein content

According to Rojas-Molina *et al*. (2008), cereal grains provide human populations from developing countries with about 50% of their dietary protein. More importantly, 70% of the protein intake, for economically disadvantaged people, is attained from cereals and grains. However, cereals and grains do not provide a nutritionally balanced source of protein, such as the essential amino acids, lysine and tryptophan. These amino acids are essential to both human and animal health (Rojas-Molina *et al*., 2008).

Sefa-dedeh *et al.* (2004) reported that nixtamalization can slightly reduce protein content; however, the decrease is not significant. Soaking maize kernels in an alkaline solution causes changes in proteins through cross-linking, hydrophobic interaction, degradation, denaturation or the formation of lysinoalanine, which affect these protein contents. Nixtamalization causes a decrease in the protein digestibility of maize, from 66 to 44.44%. As mentioned before, changes occur in proteins through many processes leading to a reduction in protein digestibility (Udomkun *et al.*, 2017). According to Carlos *et al.* (2018), variations in protein structure, through the development of secondary crosslinks or iso-peptide bonds, may reduce digestibility, by blocking the active sites of enzyme attack or inducing the formation of compounds that inhibit digestive enzymes. Although protein digestibility is reduced, nixtamalization has been reported to improve the availability of the essential amino acids, lysine and tryptophan, in cooked tortillas, thus, improving overall protein quality (Escalante-Aburto *et al*., 2020). Wacher (2003) notes that lysine and tryptophan increased by 2.8 times; additionally, the ratio of isoleucine to leucine increased by 7.8 times.

Therefore, a study by Sunico *et al.* (2021) supports the statement as mentioned earlier. They conducted a study in which various nixtamalization processes were applied to quality protein maize (QPM) flours. These processes included traditional nixtamalization, classic nixtamalization and ecological nixtamalization. The reported findings indicated that there was a significant increase in lysine and tryptophan content. However, the highest lysine and tryptophan content were found in the ecological nixtamalized flour, followed by classic nixtamalized flour and traditional nixtamalization flours, respectively. The results were also found to be significantly different from each other, except for the classic nixtamalized and traditional nixtamalization flour's tryptophan levels. Therefore, the researchers also recommend the importance of selecting the appropriate nixtamalization process, in order to achieve the desired results.

Another commonly adopted method by the vegetarian and vegan community is protein complementation, which involves combining complementary protein sources in a single meal (Mariotti and Gardner, 2019; van Vliet, Burd and van Loon, 2015). According to Young and Pellett (1994), plant-based proteins, such as legumes, cereals, nuts, seeds and plant-based butters, offer diverse qualities and essential amino acid compositions. The authors suggest that combining different varieties of plant-based proteins within an existing meal, can actively promote good nutrition. This practice aligns with the approach discussed in Section 2.4, where, incorporating nutrient-dense foods with maize, serves as an effective strategy to address its nutritional imbalances.

2.7.4 Niacin (vitamin B_3) content

Maize contains B-vitamins, such as thiamine, riboflavin, niacin, pantothenic acid, piridoxine, folate and biotin. These water-soluble vitamins are located in the endosperm and germ of the kernel, with the highest concentration present in the aleurone layer (Nuss and Tanumihardjo, 2010). Specifically, maize contains niacin (vitamin B_3) in a bound form, rendering it biologically unavailable to humans (Suri and Tanumihardjo, 2016). However, the nixtamalization process causes a significant increase in the niacin content, as the alkaline cooking results in the release of the bound niacin, making it available for human absorption (Suri and Tanumihardjo, 2016). Nixtamalized maize, prepared through the traditional nixtamalization process, is reported to have a higher level of niacin content, as compared to non-alkaline cooked maize (89 μ kg^{-1} to 66 μ kg^{-1}). Wacher (2003) reported that nixtamalized maize had a 34.8% increase in niacin over non-alkaline cooked maize. Following the nixtamalization process, it was observed that the endosperm accounts for approximately 68% of the total niacin content, while the germ contributes around 5.5%. Furthermore, the analysis revealed that approximately 26% of the total niacin content was present in the nejayote, a by-product of the nixtamalization process (Bressani, 1990). According to Naggayi *et al.* (2020), in countries where the consumption of maize is high, nixtamalization has the potential to decrease pellagra, an endemic disease caused by a deficiency of niacin (vitamin B_3) in the body.

Pellagra is a disease, resulting from a deficiency of niacin and/or its precursor tryptophan (Prinzo, 2000). The insufficiency of maize, in both these nutrients, poses a high risk of pellagra for populations who consume maize, as their staple food. Prinzo (2000) further notes that populations located in Central America had limited instances of pellagra, despite the high consumption of maize. It was further hypothesised and proven that this phenomenon was later attributed to the enhanced bioavailability of vitamin B_3, resulting from traditional nixtamalization (Harper, Punekar and Elvehjem 1958).

2.7.5 Mineral content

I. Calcium

According to Suri and Tanumihardjo (2016), nixtamalized maize serves as a source of calcium, due to the cooking and steeping of maize in the $Ca(OH)_2$ solution (Mendoza *et al.*, 1998). Interestingly, non-nixtamalized whole, dry maize kernels are very low in calcium, containing only 7 mg/100 g (Suri and Tanumihardjo, 2016). Therefore, maize itself is not a reliable source of calcium. A study by Bressani, Turcios and de Ruiz (2002), found that the average calcium content of nixtamalized maize was 170 mg/100 g, which is almost an 18-fold increase.

II. Iron

Non-nixtamalized dry maize contain about 2.7 mg iron per 100 g. The majority of the iron is located in the endosperm (76%), while the germs contain about 18% (Bressani, Turcios and de Ruiz, 2002). Nixtamalization has been observed to cause a slight reduction in iron levels, in whole maize. However, these reductions primarily occur in the endosperm, while in the germ, the iron content tends to increase (Bressani, Turcios and de Ruiz, 2002). Bressani *et al*. (2004) demonstrated that the iron content of whole maize kernels remained unaffected by the alkalinity of the $Ca(OH)_2$ solution, used in nixtamalization, as well as by the cooking process and steeping time. Additionally, cooking maize in either a $Ca(OH)_2$ solution or water did not change the iron content. However, it was observed that prolonged steeping time of nixtamalization was associated with a significant decrease in iron content (Bressani *et al*., 2004). It is important to mention that a high concentration of calcium may also inhibit iron bioavailability (Suri and Tanumihardjo, 2016). Bressani *et al.* (2004) further advise that if iron absorption is a priority, soaking maize in water after cooking, is recommended. Additionally, phytic acid inhibits iron absorption, which reduces its bioavailability in maize (Suri and Tanumihardjo, 2016). However, the nixtamalization process reduces phytic acid by about 20%, adequate to potentially improve iron absorption by the body (Bressani *et al*., 2004).

III. Magnesium

Maize contains about 127 mg magnesium per 100 g whole kernels. Research conducted on magnesium is comparatively limited, compared to studies on iron and zinc. However, it has been established that magnesium does form complexes with phytates that hinder its absorption (Bohn *et al*., 2004). A study by Mendoza *et al*. (1998) showed that magnesium content increased significantly, after nixtamalization and subsequent preparation into dough and tortillas, from 165 mg/100 g in unprocessed maize, to 180 mg/100 g in dough and tortillas.

IV. Phosphorus

The phosphorus content present in maize is around 210 mg/100 g, found mainly as phytic acid (Suri and Tanumihardjo, 2016). Phytic acid, found in cereals, legumes, oil seeds and nuts, functions as the primary storage form of phosphorus, constituting approximately 1 to 5% of the total weight (Vats and Banerjee, 2004). Approximately 90% of the phytic acid is concentrated in the germ of the maize kernel, with the remaining 10% present in the aleurone layer. According to Hambidge *et al.* (2005), phytic acid reduces the bioavailability of iron and other nutrients. The physical removal of maize bran and germ has been found to reduce the phytic acid content by approximately one-quarter to one-third (Proulx and Reddy 2007). Various heat treatments applied to fresh and dried maize have been shown to decrease the content of phytic acid. For instance, a study conducted by Khan, Zaman and Elahi (1991) observed that boiling maize led to an 18% reduction in phytic acid content. Whereas roasting maize, resulted in a decrease of phytic acid, ranging from 24 to 53%, in the same study. Bressani *et al.* (2004) reports that the nixtamalization process reduces phytic acid by about 20%.

V. Sodium

Maize naturally has a very low in sodium content, typically around 35 mg/100 g. However, many maize food products acquire sodium during processing, such as sodium hydroxide added to tortillas. Salt is often added for flavour enhancement purposes, leading to a significant increase in sodium content, especially in snack foods (Suri and Tanumihardjo, 2016). A study by Odukoya *et al.* (2022) demonstrated an increase in the sodium content of nixtamalized maize when processed, using sodium hydroxide as the alkaline medium in the nixtamalization process.

VI. Potassium

There is limited research on the effects of processing on potassium content in maize. According to Suri and Tanumihardjo (2016), whole-grain maize flour contains relatively higher levels of potassium, with a content of approximately 315 mg/100 g. On the other hand, degermed flour, which has had the germ removed, exhibits a substantially lower potassium content, measuring around 90 mg/100 g. This indicates that the potassium content can vary, depending on the processing and removal of certain components in maize flour. Further-processed maize products, such as tortillas and extruded chips, contain 186 and 144 mg/100 g, respectively (Suri and Tanumihardjo, 2016). Moreover, according to Odukoya *et al*. (2022), the use of potassium hydroxide as the alkaline medium in nixtamalization, resulted in a significant increase in the potassium content of the processed maize. The impact of the medium type on the mineral content of a particular mineral, in nixtamalized maize, is consequently highlighted.

2.8 INTRODUCING NIXTAMALIZATION TO SOUTH AFRICAN CONSUMERS

As mentioned previously by Du Plessis (2003), maize is a staple for many South African households; additionally, it is the country's most produced crop (FAO, 2022). Its significance in the food supply industry cannot be understated, as it provides an average of 250 to 300 g of food to the daily diets of South Africans (FAO, 2022). Furthermore, the Animal Feed Manufacturers Association (AFMA) reports that approximately 40% of the maize produced in South Africa is used for animal feed, thereby contributing to the country's livestock industry (AFMA, 2017). More specifically, South Africa produces 4.1 million tons of maize annually for human consumption and 3.9 million tons for animal feed, with white maize allocated for human consumption and yellow maize for animal feed (AFMA, 2017). As stated previously by Ponce-García, Serna-Saldivar and Garcia-Lara (2018), significant maize losses occur during the storage phase, following post-harvest. According to Tefera (2012), poor post-harvest management can result in 20 to 30% of losses, approximating an estimated annual monetary value of over US $4 billion. Therefore, post-harvest losses pose a critical constraint in enhancing food and nutritional security in Africa. However, in addition to alleviating losses caused by mycotoxins, the process of nixtamalization can improve the nutritional quality of maize and maize-based products, thus, positively contributing to the nutritional status of its consumers (Palacios-Rojas *et al.*, 2016). The subsequent discourse will elucidate the various aspects involved in accepting novel food processing techniques.

Introducing new food processing technologies aims to make food safer, more nutrient dense and tastier, with an increased shelf life. The purpose of food processing is to convert agricultural raw materials into delicious and nutritious foods, i.e., products that provide nutritional support to the body, upon consumption. However, consumers have limited trust in how foods are processed (Meijera *et al.*, 2021). Food processing started as early as humans first discovered how to make and control fire, as a way of preparing food, as the cooking or baking of foods significantly impacted on their palatability, digestibility and safety. Subsequently, the development of preserving food for future use, manifested the second wave, in food processing. However, the purpose of food processing today is to make food safer to eat over extended periods and more nutritious and tastier, with an increased storage life, which consumers find appealing. This has resulted in a wide range of new foods, such as instant soups, sauces and extruded breakfast cereals (Bruhn, 2007; Meijera *et al.*, 2021).

However, according to Rapaport (2019), food processing by the food industry has gained increasingly negative opinions, as using terms such as “ultra-processed’’ food has been linked to the increase in non-communicable diseases, such as diabetes and heart disease. This has resulted in a loss of trust by consumers in processed foods and a failure to recognise the importance of these processes, in converting agricultural raw materials into safe foods (Monteiro *et al.*, 2014). Food manufacturers are required to follow the Codex General Standard for the Labelling of Pre-packaged Foods (CODEX STAN 1-1985), which declares that certain information about the product, such as the name of the food, a list of ingredients, the name and address of the manufacturer, packer, distributor, importer, exporter, as well as the country of origin, should be listed on the label. However, detailing the type of processing technique, used for a product, is not mandatory (FAO of the United Nations, 1991). Although processing is not part of compulsory labelling, claims can be used to provide further information, as long it is within the Codex General Guidelines on Claims. The main principles of the guidelines are that claims should be correct, not misleading or deceptive, and not create an erroneous impression regarding the character of food, in any respect. In addition, manufacturers should be able to justify the claims (FAO of the United Nations, 1979).

In a study by TNS Opinion & Social (2010), 79% of European consumers were concerned about food safety, regarding foods being contaminated with chemical residues during processing, as media outlets, such as the news, reported processed food as unsafe. Consumers' concerns with food safety further highlight their lack of trust in how food is produced, formulated and processed (Meijera *et al.*, 2021). These concerns could be addressed through product transparency, by creating systems where the origin of food can be traced, throughout its production chain (Knutsen *et al.*, 2017). It is possible to gain consumer trust by providing information about a product (Hansen *et al.*, 2003). However, most of the general public does not view food manufacturers as trustworthy sources of information (TNS Opinion & Social, 2010).

TNS Opinion & Social (2010) further notes that manufacturers may be unwilling to share all information about a particular food product, because this could give competitors a competitive advantage. The food industry continues using trade secrets, in addition to patents, to preserve its competitive edge. Consumers are becoming increasingly heterogeneous in their choices, and intangible benefits, such as health, sustainability, authenticity and ethics are hard to convey. Increasing transparency in food processing could help restore consumer trust in packaged foods, alleviating concerns about food safety and security.

As mentioned, processed foods provide safe yet nutritious foods, with an extended shelf life. A food's safety refers to the fact that it does not cause immediate physiological harm to a consumer when consumed; in other words, the consumer does not get sick after consuming the food (Zeuthen and Bøgh-Sørensen, 2003). This was not always the case, as foodborne diseases were common throughout human history and contributed significantly to premature deaths, for many years. During the past few decades, food processing has evolved substantially, to make foods safer for consumption. While some preservation methods, such as wild fermentation, curing through salting, smoking and drying, have been known for centuries, there was no understanding of their functions. As a result of an improved insight of the cause and effect of modern food processing technologies, food manufacturers can now maximise beneficial effects, while minimising detrimental ones (Meijera *et al.*, 2021). For example, the use of less nitrite to cure meat, while maintaining safety and quality, was one way to avoid potentially carcinogenic by-products (Lineback and Stadler, 2008).

Over two centuries ago, Nicolas Appert invented the canning of foods, revolutionising food processing. By inactivating pathogenic microorganisms, canning not only prevented the spread of many food diseases, but also prevented recontamination, due to the sealed containers, which protected the food from the environment (Summers, 2015). Appert's earliest experiments involved sealing foods in glass vials, by melting the ends of the vials over a flame. Canning has since evolved, as a wide range of materials, sealing techniques and heating methods can be employed nowadays. The thermal treatment of foods inhibits the growth or inactivates food pathogens/microorganisms, in most raw foods. These microorganisms harm humans, as they attack the digestive system, upon consumption. Thermal treatments inactivate these microorganisms, by making them incapable of reproducing or destroying them (Qiu *et al.*, 2019).

Besides ensuring food safety, processing improves the nutritional value of foods. According to Burri, Bertoli, and Stadler (2009), extensive research has been conducted on the impact of food processing on the bioavailability of vitamins and minerals, as phytochemicals in plant foods. For example, several studies have demonstrated that polyphenols, present in foods, have health benefits and processing may contribute to their formation. Several processed foods contain polyphenols, including tea and coffee. The thermal treatment of coffee makes the beverage palatable. It changes the polyphenol profile, resulting in a more complex structure, characterised by more potent antioxidative properties, than their precursors (Yanagimoto *et al.,* 2002). Additionally, the nutritional value of foods can also be reduced. This is particularly true for heat-sensitive nutrients, such as vitamins C, B_1, B_2 and B_6, and folic acid. However, it is possible to replenish such losses by adding vitamins after the thermal processing step, such as by adding a dry mix or coating the product, after the processing step (Aherne *et al.*, 2010).

Most consumers are unaware of how commercial food products are manufactured on an industrial scale, which almost always involves processing technologies. Food industry processing technologies are sometimes based on similar mechanisms as home food preparation methods, although they may differ in scale and equipment (Meijera *et al.*, 2021). The tendency of consumers to be suspicious of technology in general, especially in the food domain, can be attributed to several factors (Giordano *et al.,* 2018). Firstly, consumers are concerned about possibly ingesting an unknown component, which could pose a safety risk to their health. Secondly, consumers deem processed foods as reducing food's naturalness. Lastly, processing raises issues, such as the implications new technologies pose to the environment and society.

A technology's perceived benefits and risks can influence its acceptance (Bearth and Siegrist, 2016). Consumer acceptance of novel technologies is influenced by familiarity with manufacturing technology, but production methods that deviate from traditional methods, are less acceptable. As a result of pressure cooking at home and irradiation's association with radioactivity, high-pressure technology sounds less frightening than irradiation (Rollin, Kennedy and Wills, 2011).

To increase the acceptance of new technologies, consumers should be informed and made aware of the benefits, whereas awareness of risks, decreases acceptance. Consumers need information about the production technology, but they also have to trust the information they receive (Frewer *et al.,* 2011). According to Giordano *et al.* (2018), European consumers responded negatively to genetically modified foods. It was then established that when informing consumers of new processing technologies, it is essential to thoroughly check their responses to the terminology, used to describe the process. Thus, the terminology used when relaying transparent information about a product's processing, plays an important role. For example, in a study by Bearth and Siegrist (2016), the use of the word ''ionization'' instead of ''irradiation'' increased consumer acceptability among American consumers. Another example can be seen in a study by Rozin, Fischler, and Shields-Argeles (2012), where contradicting attitudes of ''prolonged shelf-life'' where observed by consumers as reduced freshness and possibly a reduction in the food's naturalness, whereas retailers appreciate the improved quality of the product. Thus, mutual trust and open dialogue would help both parties to comprehend the different perspectives. For nixtamalization to be successfully introduced as a new processing technique in South Africa, it is crucial to establish consumer trust and acceptance. This entails fostering positive attitudes towards the process itself and the products derived from it.

2.9 SOUTH AFRICAN FOOD PREFERENCES

Maize is a staple cereal in South Africa, which finds extensive utilisation in the production of numerous products, both commercially and at home. According to Soro-Yao *et al*. (2014), most maize is primarily consumed as beverages, breakfast porridges and snack foods. Generally, maize is a good source of carbohydrates, fats, proteins and some essential vitamins and minerals. The macro- and micro-nutrients found in the maize kernel play a significant role in improving its quality, for both human food and animal feed (Kaul, Jain and Olakh, 2019). According to Agrawal and Gupta (2010), maize protein is high in the ratio of leucine to isoleucine, but lacks tryptophan and lysine, which mean that it does not contain two of the nine essential amino acids, making it an incomplete protein, which can support maintenance, but not growth (Brown, 2018). However, some essential nutrients are present in bound form, making it inaccessible to the human body. As mentioned in the previous discussions, the process of nixtamalization offers various benefits, such as reduced mycotoxin content, increased product shelf-life, enhanced nutritional value, and improvement in aroma and flavour. These changes are particularly advantageous in enhancing the bioavailability of key nutrients, such as protein, iron, niacin (vitamin B_3) and calcium content, present in the kernel (Ekpa *et al*., 2018).

Food availability, accessibility and choice influence food consumption. Several factors affect the choices people make when it comes to food, including geography, season, education, demography, disposable income, religion, culture, ethnicity and social networking (Kearney, 2010). Moreover, Ronquest-Ross, Vink and Sigge (2015) note that South Africa's diet have become more Westernised, since 1994. Westernised diets are characterised by the consumption of processed foods and meats that are high in fat and salt, refined grains that are high in sugar, and consuming less fruit and vegetables (Cordain *et al.*, 2005). These diets have the potential to contribute to hypertension, elevated cholesterol levels, obesity and inflammation. Consequently, individuals following such dietary patterns, face an increased risk of developing cardiovascular diseases, diabetes and cancer (Koene *et al.*, 2016).

In South Africa, particularly, the responsibility of household food choices lies predominantly with women, who also bear the primary responsibility of grocery shopping. Their selection of food is commonly influenced by price, which tends to hold paramount influence over taste, health, nutritional value, safety and ease of preparation (Ronquest-Ross, Vink and Sigge, 2015). Economically, foods that are energy dense are more affordable, compared to healthier food options. Therefore, price-conscious consumers tend to select foods with a high content of refined cereals, sugar and fat, while having a relatively lower proportion of meat, fish, vegetables and fruits (Drewnowski and Darmon, 2005). Furthermore, Temple *et al.* (2011) found that healthy diets can cost as much as 69% more than the average diet of most South Africans, proving that eating healthy is unaffordable to most. Consequently, lower-income individuals are constrained in their ability to achieve a diverse and balanced diet (Temple and Steyn, 2009).

Various prospective cohort studies have demonstrated a significant reduction in coronary artery disease and stroke risks among people who consume a diversified diet, consisting of vegetables, fruits, nuts and whole grains (Hu, 2003). According to Hu (2003), the protective effects of these foods are thought to be influenced by a range of beneficial nutrients they contain. These nutrients include mono- and polyunsaturated fatty acids, omega-3 fatty acids, antioxidant vitamins, minerals, phytochemicals, dietary fibre and plant protein.

2.10 MAIZE AS A SNACK FOOD

Maize is extensively used in the production of snack foods (Ranum, Peña-Rosas and Garcia-Casal, 2014). The term ‘‘snack’’ describes the consumption of food or beverages between meals. Generally, snack foods are high-caloric, sodium-rich, sugary and/or fatty foods (Taillie *et al.*, 2015). There is a very wide range of snack foods available today, including potato chips, corn chips, alkali-cooked corn tortilla chips, pretzels, popcorn, puffed foods, baked and fried foods, half-foods, meat snacks, and rice-based snacks (Robertson, 2013). Snack foods can be freshly prepared at home, such as sliced fruit or cold cuts of leftover meat (Robertson, 2013). Popcorn, particularly, which is available in both sweet and savoury flavours, has gained and continues to gain widespread consumer acceptance, as one of the most prevalent forms of snack foods. Its appeal is particularly prominent in cinemas, amusement parks and schools (Iken and Amusa, 2010). Conveniently, snack foods can also be purchased at a local supermarket, where they are packaged to be less perishable, easy to handle and travel with. Snack foods, purchased at a supermarket, often require no preparation and are often a quick and cheaper alternative to homemade snacks. Most snacks contain preservatives, sweeteners and appealing ingredients, such as chocolates and different flavoured chips (Reardon *et al.*, 2021).

Snack food manufacturers classify snack foods into three categories. These categories are first-generation snack foods, namely natural products used for snacks, such as nuts, and potato chips (Chinnadurai and Sequeira, 2016). Second-generation snack foods, often known as directly expanded snacks, is primarily produced through extrusion. These snacks are composed of single ingredients that undergo shaping and expansion processes, resulting in the creation of popular items, such as puffed snacks. These products can be baked or fried, and then seasoned (Hui & Sherkat, 2005). Lastly, third-generation snacks (also referred to as indirectly expanded snacks) are multiple-ingredient snacks, which are mixed during the extrusion process, dried into a shelf-stable form (pellets) and then expanded by heat, such as oil- or air-fried, or microwaved at a later stage (Van der Sman and Broeze, 2014). The extrusion process is versatile, highly productive, low-cost, energy-efficient and lacks effluents. Extrusion consists of forming and shaping a dough-like material, by forcing it through a restriction, known as a die. The cereal industry uses this technology extensively to convert cereal flour by kneading, cooking, forming and texturising it into ready-to-eat foods, such as noodles, pasta, breakfast cereals, baby foods and snack foods (Bouvier & Campanella, 2014). Corn, potato, rice and wheat are used directly, and indirectly, for expanded snacks (Bouvier & Campanella, 2014). There is a high concentration of starch and energy in these snack foods, with little nutritional value, such as micronutrients and proteins.

A shift away from healthy foods has resulted from changes in agricultural systems and technological advancement, which has led to the promotion of cheap, readily available, nutrient-poor and energy-dense foods (Popkin, 2015). Snacks are consumed more spontaneously than regular meals, which could suggest that frequent snack consumption may be responsible for weight gain (de Graaf, 2006). Snack consumption has increased over the past few decades and the trend will continue. It has been noted that increased snack consumption has contributed to the increase in obesity (Jahns, Siega-Riz and Popkin, 2001; Zizza, Siega-Riz and Popkin, 2001). Most commercialised snacks have a high-energy density. Sweet snacks, such as cookies, cakes, pies, ice cream and chocolate candy bars contain high sugar and fat contents. Their average energy content is about 1 500 to 2 000 kJ/100 g (Whybrow, Mazlan and Stubbs, 2005). Savoury snacks, such as potato chips, are also energy-dense products, with about 2 200 kJ/100 g (de Graaf, 2006).

However, consuming healthy snacks could reduce the harmful effects of snacking, thereby promoting and facilitating a nutrient-dense and health-promoting diet (Hess and Slavin, 2014). Several factors can be considered in defining a snack, including time of day, type of food consumed, amount of food consumed, location of consumption or a combination of several factors (Hess, Jonnalagadda, and Slavin, 2016).

With the increasing pace of life, people tend to eat "ready to eat" food, i.e., foods that can be consumed quickly, without going through any further processing (Panak Balentić *et al.*, 2018). Hess, Jonnalagadda, and Slavin (2016) further note that motivations to snack vary greatly, based on appetite, current environment, social and cultural factors, and cognitive factors. According to Bellisle (2014), snacking when hungry is associated with consuming foods that promote feeling fuller for longer periods, whereas snacking, in the absence of hunger, leads to consuming foods that are high in fat, sugar and salt. Consequently, snacking unnecessarily promotes weight gain and poor nutrition. Moreover, the choice of snacks, as well as portion sizes, may be influenced by the location or setting in which they are consumed (Kerr *et al.*, 2010). O'dwyer *et al.* (2005) note that eating at home or at the workplace is associated with healthier snacks, whereas eating at other locations, tends to result in larger snack sizes, containing more fat and fewer fibre.

Snacking can also be influenced by social culture, food culture and socioeconomic status. According to Hermans *et al.* (2010), studies have proven that eating companions' portion sizes are influenced by how much food they consume, a phenomenon known as "social modelling". If companions consume a large portion of food, the person eating with them, also tends to eat more.

According to Glanz *et al.* (2005), the food environment is defined as the "collective physical, economic and socio-cultural settings”. These are opportunities and conditions influencing people's consumption of food and beverages, and nutritional status of an individual. Environmental cues about earlier individuals' food intake and choices, such as empty food wrappers, can still influence an individual's intake, in the absence of a companion (Prinsen, de Ridder, and de Vet, 2013). Hess, Jonnalagadda, and Slavin (2016) state that the consumption of snacks may also be influenced by celebratory social occasions, as well as the availability of or desire for tempting foods. However, people who suffer from food insecurity often rely on snacking, to skip meals. Food insecurity affects individuals, by restricting or preventing them from accessing adequate food for an active and healthy lifestyle (Zizza, Duffy and Gerrior, 2008). The trend toward increased snacking indicates that snacks may serve different roles in the diet and have other health effects, based on socioeconomic status (Hess, Jonnalagadda, and Slavin, 2016).

Cognitive factors, such as emotional eating, also contribute to the motivations behind snacking. Emotional eating has often been associated with overeating, because it can be defined as the tendency to indulge in foods, to cope with negative emotions, like anxiety or irritability. Based on psychosomatic theory, emotional eaters cannot distinguish hunger from the physiological state, triggered by negative emotions (Brunch, 1964). Since eating during emotional times is a behavioural response, emotional eaters eat more when they experience negative emotions. In contrast, normally this would cause a loss of appetite, since emotions cause physiological changes, similar to satiety (Adriaanse, de Ridder and Evers, 2011).

2.11 CONCLUSION

According to existing literature, maize holds a prominent position as a staple crop in South Africa. Its applications extend beyond the food industry, to include textiles, pharmaceuticals and animal feed. In the field of consumer science, maize plays a crucial role in providing affordable means of energy consumption, for impoverished communities. However, the nutritional profile of the maize kernel itself is imbalanced. Relying solely on maize as the primary staple, without dietary diversification, can lead to nutritional deficiencies among consumers.

To address this concern, the process of nixtamalization presents promising advantages. This processing technique enables bound nutrients, such as vitamin B_3, lysine and tryptophan, to become more readily available for absorption, by the human body. By subjecting maize to nixtamalization, it becomes possible to enhance its nutritional value and alleviate the potential adverse effects, associated with exclusive dependence on this staple crop.

However, the introduction of nixtamalization as a novel processing technique, requires consumer acceptance and trust. Therefore, implementing any new method in food processing requires consumers to have confidence in its safety and benefits. Hence, effective communication and adequate information are required for a successful introduction. By highlighting maize safety concerns and nutritional imbalances, acceptance and trust could be achieved.

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CHAPTER 3: CONSUMER ACCEPTABILITY OF NOVEL NIXTAMALIZED MAIZE PRODUCTS

3.1 INTRODUCTION

About eight million tons of maize is produced in South Africa under varying climatic conditions, with the major producing provinces being Free State, North West, Mpumalanga, and KwaZulu-Natal. Approximately 45% of the country's agricultural sector's gross domestic product comes from maize, which is grown by both commercial and subsistence farmers (Adisa *et al.*, 2019). Additionally, maize is the most important grain crop in South Africa, which serves as a staple food for a large proportion of the population as well as feed for animals (Adisa *et al.*, 2019). However, maize as a staple food is unbalanced in essential nutrients such as the amino acids lysine and tryptophan as well as other vital nutrients including vitamin C, B-vitamins, iron, and iodine (Nuss and Tanumihardjo, 2010). However, the process of nixtamalization resolves the imbalance of essential nutrients that are present in the maize kernel (Wacher, 2003).

Nixtamalization is the traditional process of cooking whole maize kernels in an alkaline medium of $Ca(OH)_2$ or slaked lime. Once the maize is cooked, it is steeped for 12 hours or overnight and then washed, to remove the pericarp and residual alkali (Argun and Argun, 2018). The process increases the bioavailability of the bound niacin (vitamin B_3) which can be absorbed in the body, additionally, playing a significant role in preventing pellagra. In addition, nixtamalization enhances the availability of iron and tryptophan to be more readily absorbed in the body. Thus, the process of nixtamalization enhances the nutritional quality of the grain (GrainSA, 2019). Furthermore, nixtamalization effectively reduces mycotoxins produced by *Fusarium verticilloides* and *Fusarium proliferatum* up to 90 to 94% (Pandey, Ghosh and Waghmare, 2019). Moreover, GrainSA (2019) further indicates that calcium and protein quality are improved, with the addition of nixtamalized maize serving as a source of dietary fibre, which is attributed to the increase in the digestibility of starch granules due to nixtamalization.

Overall, this chapter comprises two phases: (i) product development; and (ii) sensory analysis, to determine consumer acceptability of novel nixtamalized maize products.

Furthermore, this chapter outlines the processes the researcher followed, and the materials and methods to develop nixtamalized maize products. It includes the (i) research design, (ii) target population and sample size (demographics), (iii) data collection, (iv) data analysis and (v) results and discussions.

Overall, the aim of this chapter was to develop novel nixtamalized maize products for the South African consumer and to determine the acceptability thereof for shelf readiness, through product development and sensory analysis.

3.2 RESEARCH DESIGN

This study utilised a quantitative research design approach. Quantitative research encompasses a range of methods concerned with systematically investigating social phenomena, using statistical or numerical data. Therefore, quantitative research involves measurement and assumes that the studied phenomena can be measured. It sets out to analyse data for trends and relationships, and to verify the measurements made (Watson, 2015).

In this chapter, the process of nixtamalization was used to develop three novel maize products as well as determine the consumer acceptability of the products. The newly developed products included two vegetarian maize-based products and a maize chip. The nixtamalized products' consumer acceptability was determined, using a consumer's liking task (hedonic scaling), while readiness for product introduction into the market, was tested by using just-about-right (JAR) scales. The sensory analysis was completed in three phases. The purpose of the first phase (JAR profile 1) was to determine which of the three products the consumer panel found the most acceptable. In addition, second phase (JAR profile 2) involved improving on the attributes the panel were not pleased with in the first phase. Lastly, the third phase (JAR profile 3) involved further refining the product to meet consumer acceptance. Additionally, a questionnaire consisting of closed-ended and open-ended questions was employed to evaluate the respondents existing knowledge regarding nixtamalization and nixtamalized products, as well as their attitudes towards the process and the new products. A detailed discussion of the findings from the questionnaire is presented in Chapter 4.

The study has two approaches: exploration and description. According to Babbie (2020), exploratory studies serve three purposes. Firstly, it aims to provide a better understanding and satisfy the researcher's curiosity. Secondly, it tests the feasibility of undertaking a more meticulous study. And lastly, it aids in developing methods and procedures, to be employed during the study. According to Babbie (2020), a descriptive approach is when the researcher observes and then describes what was observed. He further notes that scientific descriptions are precise and accurate. This study is descriptive, in that nixtamalization processes are described and consumers' acceptability of the products are explained, using sensory data.

The researcher did a study of literature on the nixtamalization process and the products that could be developed in the South African context. To our knowledge limited information is available about maize plant-based products and snack foods that are produced in South Africa, through the process of nixtamalization.

Each of the three developed products underwent sensory analysis, using JAR scales and a consumers liking task. Consumers indicated their overall liking of each product, using the 9-point hedonic scale, ranging from 1 = "dislike extremely" to 9 = "like extremely", with a neutral value of 5, which indicates "neither like nor dislike". In addition to consumer liking task, shelf-readiness of four attributes (aroma, appearance, taste and mouthfeel) were measured per product using JAR tasks. Bi-polar scales with five points were applied, with 1 indicating "much less" and 5 indicating "much more", with a middle value of 3, indicating "just about right" (JAR) (Ortega-Heras *et al.*, 2019). In studies performed with consumers, these scales are employed to determine whether a particular attribute is perceived as excessive, scarce or acceptable in a product. On the scale, the extreme ends represent the level of an attribute that moves away from an ideal theoretical point in opposite directions, whereas the center is the ideal or acceptable point (Rothman, 2007).

3.3 MATERIALS AND METHODS

This section outlines the materials and methods, in terms of the process of nixtamalization, as well as the development of three novel nixtamalized maize products by the researcher. This section solely discusses the procedures the researcher followed, while completing laboratory work.

The maize used in this study was received as dry white maize kernels from a farm situated near the small town of Hoopstad in the Lejweleputswa district in the Free State province. The kernels were stored in airtight containers, in the refrigerator at 4 °C, in the Consumer Science Food Laboratory, at the University of the Free State (UFS), Bloemfontein. For this study, dried white maize kernels were used to develop new products, as white maize is the most common maize cultivated for human consumption in South Africa (Shew *et al.*, 2021).

3.3.1 Product development

This section outlines the equipment and procedures carried out during laboratory work. This phase of the study took place in the Food Laboratory and the Vegetable Processing Laboratory, at the Department of Sustainable Food Systems and Development, University of the Free State. This section includes: (I) nixtamalization process, (II) drying masa to produce flour and (III) product development.

I. Nixtamalization

The traditional nixtamalization process was employed in this study. The whole dry maize kernels were used in the process. The equipment used to carry out the process included the following: stainless steel pot; stovetop; measuring jug; measuring cups; measuring spoons; colander; latex gloves; wooden spoon; and a food processor.

Nixtamalization was carried out in a 7-step process, as mentioned in Chapter 2, Section 2.5. The process was completed according to the following ingredients and method:

Materials:

6 cups (1080 g) dry white maize kernels

4.5 litres water

4 ½ teaspoons (10.4 g) slaked lime

Method:

1. All the ingredients were added to a stainless-steel pot and brought to a boil, for 10 minutes.
2. Thereafter, the maize kernels were left to soak overnight.

3. The following day, the maize kernels were rubbed between gloved hands, to remove the pericarp.
4. The maize was transferred to a colander and rinsed under cold running water, until the water ran clear. This grain is now called *nixtamal*.
5. Thereafter, the nixtamal was placed into a Kenwood Everyday Food Processor FDP03.A0W and ground to produce masa.

II. Drying nixtamalized maize

The masa was dried in the convection oven of a Defy 4 Plate Stove DSS693 to produce flour. The flour was used in the development of new products. The masa was spread evenly on baking sheets, lined with baking paper and placed in an oven set at 100 °C, with the door slightly open, for 120 minutes. Thereafter, the dried masa was ground in a Nutribullet 600W High Speed Blender, into a fine powder. In order to remove unrefined particles, the fine powder was sieved through a sieve, with a mesh size of 0.8 mm. This process resulted in the production of masa flour. One cup (250 ml) of masa flour weighs an average of 165 grams.

III. Product development

Food product development involves stages that bring a new product to the consumer market and test its feasibility. These newly developed products can be in the form of new or different to pre-existing products or could include food products that already exist but are changed in some way in relation to the nutritional properties or improvement in the flavour of the food item (Jones and Jew, 2007).

In this study, three novel products were developed, with similar variations available in the food market. The development of the new products employed different preparation methods, which resulted in a maize nugget, a maize patty and a maize chip. The maize nugget and patty were compared against similar vegetarian options while the chip was compared against the same formulation but prepared with different methods of cooking. As part of product development, masa and masa flour were both used in the production of the new products (Figure 3.1).

Figure 3.1: Masa (left) and Masa flour (right)

a) Maize Nugget

Consumers are becoming increasingly aware of the correlation between diet, health and overall well-being, leading to an increased interest in foods with health-promoting benefits (De Smet and Vossen, 2016). Cohort studies have found that plant-based diets have positive effects on obesity, hypertension, type-2 diabetes, cardiovascular health and overall mortality (Menal-Puey, Del Ruste and Marques-Lopes, 2016). Nuggets are battered and breaded products that were made popular in American fast-food restaurants. In general, the most common nugget type is chicken nuggets, which are chicken breasts coated in a batter, rolled in breadcrumbs and fried in oil, until they are cooked through (Barbut, 2013). The aim was to develop a vegetarian maize-based nugget, with the added nutritional benefits of nixtamalization. As part of the sensory analysis, the maize nugget was tasted in combination with two other vegetarian products: a chickpea nugget (Food with Feeling, 2019) and a hashbrown (Allrecipes**,** 2021). The purpose was to compare and evaluate various factors, such as textures, flavours, and nuances. Table 3.1 shows the formulation of the maize-based nugget as well as two similar vegetarian products: chickpea nuggets and hashbrowns.

Table 3.1: Formulations of the maize nugget, chickpea nuggets and hashbrowns.

Maize nuggets		**Chickpea nuggets**		**Hashbrowns**	
Ingredients:	**%:**	**Ingredients:**	**%:**	**Ingredients:**	**%:**
For filling:		Breadcrumbs	24,8	Potatoes, grated	46.4
Mashed potatoes	15.2	Chickpeas, canned	66,1	Brown onion, chopped	11.4
Masa, wet	16.0	Oat flour	7,3	Flour	4.0

Red onion	10.9	Flaxseed powder	1.0	Egg, large	6.7
Garlic clove	0.5	Garlic powder	0,3	Sunflower oil	30.2
Ginger and garlic paste	0.2	Chicken seasoning	0,5	Salt	1.0
Garlic powder	0.1	**Total:**	**100.0**	Black pepper ground	0.3
Salt	0.5			**Total**	**100.0**
Cumin	0.1				
Masala	0.1				
Rosemary & olive seasoning	0.2				
Aromat	0.3				
Curry powder	0.2				
Mixed herbs	0.1				
For crust:					
Cornflakes, crushed	9.4				
Aromat, for crust	0.3				
Masa, wet, for crust	10.6				
Olive oil	18.2				
Vegetable stock cube	0.7				
Water	9.1				
Eggs	7.3				
Total	**100.0**				

For the maize nugget: The filling consisted of mashed potato, wet masa, red onion, garlic clove, and ginger-and-garlic paste which were blended in a Kenwood Everyday Food Processor FDP03.A0W, until well combined. The spices were blended into the masa mixture. To form the nugget, the masa mixture was formed into a 40 g ball and shaped into a nugget form. Thereafter, the nuggets were set aside, and the ingredients for the crust were prepared. For the crust of the maize nugget four bowls were laid out for each of the following: (i) vegetable stock, which was prepared with the stock cube and water; (ii) masa and Aromat mixture; (iii) whisked eggs, and (iv) crushed cornflakes. Each nugget was dipped into the stock, rolled into the masa mixture, dipped into the egg, and rolled onto the crushed cornflakes. In a frying pan, oil was heated on medium heat (heat setting 3) on a Defy 4 Plate Stove DSS693, and the nuggets were fried for five minutes until the crust was golden brown. The fried nuggets were placed onto a baking sheet and baked in the convection oven of a Defy 4 Plate Stove DSS693 heated to 180°C, for 30 minutes.

For the chickpea nugget: the aquafaba (chickpea liquid) was drained and set aside in a small bowl. The chickpeas, oat flour, flaxseed powder, garlic powder and chicken seasoning were processed in a Kenwood Everyday Food Processor FDP03.A0W until fully combined. Thereafter, 30 g of the mixture was shaped into a nugget. The nuggets were dipped into the aquafaba and rolled in the breadcrumbs. The nuggets were baked on a baking sheet for 15 minutes in a 180 °C preheated in the convection oven of a Defy 4 Plate Stove DSS693 (Food with Feeling, 2019).

For the hashbrown: Potatoes were rinsed, peeled and grated. Thereafter, the grated potatoes were rinsed in water until the water ran clear. The water was drained and the potatoes were squeezed dry with a clean dish cloth. In a medium sized bowl, the grated potatoes, brown onions, oat flour, egg, salt and pepper were mixed until well combined. In a frying pan of a Defy 4 Plate Stove DSS693, oil was heated on medium heat (heat setting 3) and three tablespoonfuls were placed into the pan. Each hashbrown was cooked for 4 minutes on each side until golden brown (Allrecipes, 2021). The maize nugget, chickpea nugget and hashbrown are shown in Figure 3.2 below.

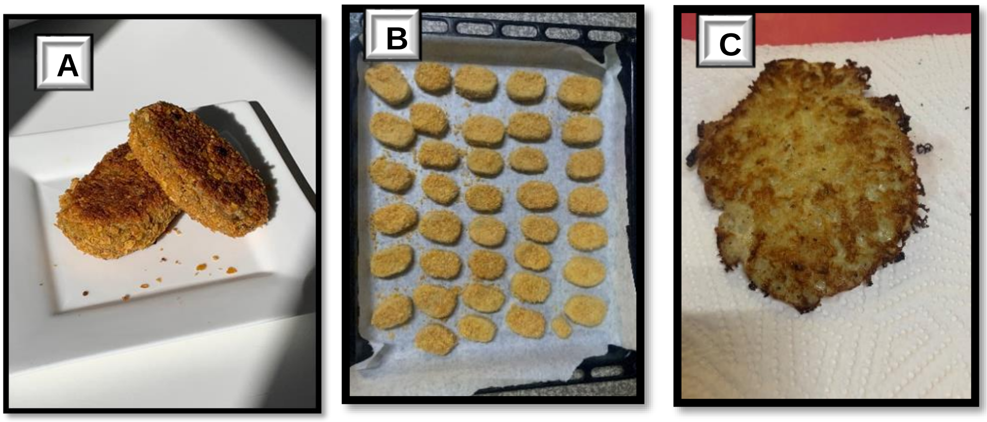

Figure 3.2: (A) Maize nugget; (B) chickpea nugget and (C) hashbrown.

b) Maize Patty

Characteristically, patties are meat products, made from minced lean meat that may or may not contain additional ingredients (Al-Mrazeeq, Al-Abdullah and Al-Ismail, 2010). Typically, a patty is a flattened disc of minced meat or vegetables, formed into a round shape (Cambridge Dictionary, n.d.). The aim of developing the maize patty was to develop a vegan-based patty, with the nutritional benefits of nixtamalized maize, as products with health-promoting properties are important to consumers. For the purpose of comparing and evaluating the attributes of each product against each other, the maize patty was tested alongside two additional samples. These samples included a black bean patty (Allrecipes, 2021) and a chickpea patty (Andrews, 2016). The formulation for all three patty samples is shown in Table 3.2.

Table 3.2: Formulations of the maize patty, black bean patty and chickpea patty.

Maize patty		**Black bean patty**		**Chickpea patty**	
Ingredients:	**%:**	**Ingredients:**	**%:**	**ingredients:**	**%:**
Vegetable stock cube	1,3	Black beans, canned	47,3	Brown onion	27,1
Water	33,5	Brown onion	10.0	Garlic clove	1,1
Masa, wet	39,2	Garlic, crushed	1.0	Olive oil	0,7
Salt	0,5	Carrots, grated	3,6	Chickpeas, canned	63,8
Mixed herbs	0,1	Green pepper, diced	7.0	Paprika	0,5
Garlic powder	0,1	Corn flour	1,1	Coriander powder	0,1
Masala	0,2	Warm water	1,8	Cumin	0,3
Cayenne	0,2	Sriracha sauce	7.0	Coriander, fresh	1,4
Cumin	0,1	Paprika	0,4	Flour	3,6
Margarine	8.0	Cumin	0,3	Olive oil*	1,4
Olive oil	16,8	Salt	0,2	**Total**	**100.0**
Total	**100.0**	Black pepper, ground	0,1		
		Brown bread, crumbed	9,5		
		Flour	10,7		
		Total	**100.0**		

For the maize patty: The vegetable stock was prepared in a jug, by dissolving the vegetable stock cube into the hot water. The stock and the wet masa mixture were cooked in a saucepan on medium heat (heat seating 3) on a Defy 4 Plate Stove DSS693, until the combined mixture reached a thick consistency. The salt, mixed herbs, garlic powder, masala, cayenne, cumin and margarine were added to the cooked masa. The mixture was rolled into 100 g balls, pressed and shaped into patties. The patties were covered in cling wrap and placed in the refrigerator for 30 minutes. In a frying pan, olive oil was heated on medium heat (heat setting 3) and each patty was fried for 5 minutes until both sides were golden brown. Afterwards, the patties were placed on a baking tray, covered with aluminium foil, and baked in the convection oven of a Defy 4 Plate Stove DSS693 oven for 25 minutes, at 180°C. The foil was removed and the patties were placed back into oven, with the heat reduced to 150 °C, and allowed to bake for an additional 5 minutes (Figure 3.3). The method of covering food with foil while cooking in the oven is called *en papillote*, which is an indirect steaming technique in which food is cooked by the steam of its own juices trapped in the foil closing (Brown, 2018).

For the black bean patty: the black bean liquid was drained from the can and set aside in a bowl. The black beans were mashed and the carrots, brown onions, green pepper and minced garlic were added and mixed until well combined. The sriracha sauce with the corn flour, warm water, paprika, cumin, salt and black pepper were whisked together in a small glass bowl. Thereafter, the sriracha sauce mixture was mixed into the black bean mixture and the breadcrumbs were added in. The flour was sifted into the bean mixture and folded in until it presented a sticky batter. Three tablespoons per patty were added into a lightly greased (cooking spray) saucepan heated on medium (heat setting 3) on a Defy 4 Plate Stove DSS693 and cooked for 5 minutes on each side (Allrecipes, 2021) (Figure 3.3).

For the chickpea patty: as with the chickpea nugget, the aquafaba was drained and set aside in a small bowl. The brown onion, garlic clove, chickpeas, olive oil, paprika, coriander powder, cumin and fresh coriander were processed in a Kenwood Everyday Food Processor FDP03.A0W until a sticky paste formed. Thereafter, the paste was chilled in the refrigerator for 40 minutes and divided into four balls. Two squares of baking paper were cut and one ball of the paste was placed between the two papers. A saucepan was used to flatten the ball into a patty shape. The patties were fried in a saucepan heated to medium heat (heat setting 3) on a Defy 4 Plate Stove DSS693 with olive oil for 5 minutes on each side (Andrews, 2016) (Figure 3.3).

Figure 3.3: (A) Maize patty; (B) black bean patty and (C) chickpea patty

c) Maize Chips

The most common type of chips are potato chips, which are thin slices of potato that are deep-fried, baked or air fried, until crunchy and flavoured with seasoning. These kinds of chips are commonly eaten as a snack (McMahon, 2022). Additionally, a wide variety of chips are available in the market, made from different vegetables and grains, such as beetroot and maize. The benefit that comes with eating maize chips, is that it contains essential nutrients, such as vitamins B6, vitamin E, as well as minerals, such as phosphorus and manganese. Typically, maize chips have a low amount of salt with no added sugar, with the addition of being served both as a snack or part of a meal, i.e., tortilla chips served with beans or guacamole (Thompson, n.d.). The maize chip had three samples all prepared the same way, however, with different cooking methods; one sample was deep-fried in oil and two samples were air fried at different temperatures and intervals. The chips were deep-fried because of the distinctive taste and texture qualities it imparts on fried food (Brown, 2018). However, deep-fried foods often contain a high fat content with almost as much as 35-44% of the total product by weight (Fikry *et al.,* 2021), hence two of the samples were air fried to provide a healthier option for the health-conscious consumer. Air frying uses hot air to cook the food which eliminates the need to use excessive amounts of oil (Zaghi *et al*., 2019). Fikry *et al*. (2021) noted that consumers are becoming increasingly aware of the advantages of low-fat and fat-free products that don't require deep-frying. Evidently, this method of cooking results in food with a reduced fat content of up to 80%, providing a healthier option for the health-conscious consumer who still wants to enjoy snack foods (Andrés *et al.,* 2013). Fikry *et al*. (2021) further notes many sensory properties may be influenced by the lower oil content, such as crust formation, palatability and appearance. Table 3.3 provides the formulations for both deep-fried and air-fried maize chips, with the former utilising sunflower oil as the cooking medium. Conversely, the air fried samples were prepared without the use of sunflower oil.

Table 3.3: Formulations for the deep-fried and air fried chip samples.

Deep fried		**Air fried 1 and 2**	
Ingredients:	**%:**	**Ingredients**	**%:**
Flour	11.9	Flour	22.4
Masa flour	16.3	Masa flour	30.6
Salt	0.3	Salt	0.7
Cheese and chives seasoning	1.3	Cheese and chives seasoning	2.4
Water	19.0	Water	35.5

Olive oil	1.5	Olive oil	2.8
Sunflower oil, for frying	49.7	Olive oil, for brushing	5.6
Total	100.0	**Total**	100.0

The dough of the chips was made in a Kenwood Chef XL Kitchen Machine KVL4100. The flour, masa flour, salt, cheese and onion seasoning were sieved in the mixing bowl of the machine, with the dough hook attached. The mixer was turned on a medium speed (speed setting 3) and the water, as well as the olive oil, were slowly poured into the flour mixture, until a dough was formed. Afterwards, the dough was kneaded manually for 1 minute, then covered and left to rest for 5 minutes. On a lightly floured surface, the dough was divided into six balls and each ball was rolled out with a rolling pin. A cookie cutter was used to cut out each individual chip.

For the deep-fried chip: The chips were deep-fried, eight at a time, in sunflower oil, heated to 180°C for 20 seconds, on each side, until golden in colour. The fried chips were placed in a colander to strain the excess oil and then placed on paper towels, to absorb any remaining oil (Figure 3.4).

For the Air fried chips 1 and 2: The chips were brushed lightly with olive oil, before placing into the air fryer. Only 12 chips were air fried at a time, to prevent them from sticking to one another. Air fried chip 1 was air fried at 160°C for 3 minutes, then reduced to 120°C for another 5 minutes, while air fried chip 2 was air fried at 80°C for 10 minutes, thereafter increased to 160°C for another 5 minutes (Figure 3.5).

Figure 3.4: Deep-fried chips from raw (left) to cooked (right).

Figure 3.5: Air fried chips from raw (left) to cooked (right).

IV. Product presentation

Upon completion of the development process, all three of the newly developed maize-based products were tasted by a consumer panel during sensory analysis. Prior to the tasting, the consumer panel were given instructions as partial training on how to sensorily evaluate the newly developed maize-based products as well as how rate the products using the consumer liking task and the JAR profile.

The patties and nuggets with their corresponding samples were cooked two hours prior to the sensory tasting. All the samples were cut into 3cm x 3cm cubes and served warm in small tasting bowls, covered with aluminium foil, before transferring to the tasting trays. Three chips, measuring 4 cm in diameter, were served at each tasting. The three samples were randomly served and presented simultaneously, each with different three-digit codes, on a white polystyrene tray, under white lights, in the sensory booths at the Sensory Laboratory, Department of Sustainable Food Systems and Development, University of the Free State. Room temperature water, ranging from 20-22°C was provided to cleanse the pallet between each sample (Andrews & Hammack, 2003), as well as a spitting cup, for the less than satisfactory samples. Respondents were rewarded with an instant coffee sachet for their participation in the study (Figure 3.6).

Figure 3.6: Tasting tray with three samples.

3.3.2 Data collection

Data was collected during sensory tasting of the three developed products. To obtain the data that presented consumer acceptance of the three products, a 9-point hedonic scale was used to indicate consumer liking. In addition, JAR scales were used to determine shelf readiness of the three products' three variations, for four attributes.

I. Consumers' overall liking task, by using hedonic scaling

The most widely used scale, for measuring food acceptability, is the nine-point hedonic scale (Lim, 2011). The nine-point hedonic scale used in the consumer's overall liking task (Figure 3.7) consists of nine categories: 1 (dislike extremely); 2 (dislike very much); 3 (dislike moderately); 4 (dislike slightly); 5 (neither like nor dislike); 6 (like slightly); 7 (like moderately); 8 (like very much); and 9 (like extremely). The panellists were asked to taste the sample and rank it on the nine-point scale, by marking one of the categories (Stone & Sidel, 2004). It is important to point out that this scale is used to indicate the position of a sample on the scale, rather than a value of a rating (Wichchukit and O'Mahony, 2015).

1	2	3	4	5	6	7	8	9
Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

Figure 3.7: Nine-point hedonic scale (Stone & Sidel, 2004).

II. Correlation between attributes

To identify the most influential factor, correlation analysis was conducted to predict consumers' attitudes toward the developed samples and establish relationships between all variables. Correlation readings usually indicate a 'no/negligible to very strong' relationship between variables (Quinnipiac University, 2013). The definitions of correlation values are as follows: 0-0.19 is regarded as very weak; 0.2-0.39 as weak; 0.40-0.59 as moderate; 0.6-0.79 as strong; and 0.8-1 as very strong (Shah, 2020). After predicting consumers' attitudes towards the developed samples, the variables can be classified into two groups: 'important determinants' and 'least important determinants', based on their level of influence as identified by previous research (Jaafar *et al*., 2012).

III. Just-about-right (JAR) scaling

The consumer panel were asked to tick a box on the five-point JAR scale, indicating how they rated the sample (Figure 3.8). Each sample was evaluated on four attributes, namely appearance, aroma, mouthfeel and taste. The ballot sheets of each product are available as Appendix B.

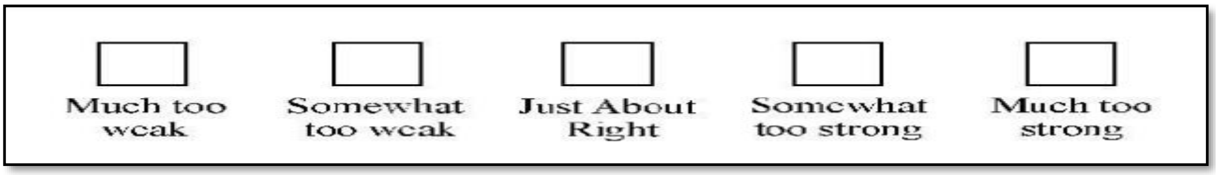

Figure 3.8: Five-point JAR scale (Moskowitz *et al.,* 2008).

The analysis of JAR scales treats all attributes as independent of one another. However, attribute interactions are often known to the product developer and sensory analyst, and their expert knowledge is key in devising a successful product reformulation strategy, based on JAR scale data. It is possible for the adaptation of one attribute to have a positive effect on other attributes, thereby eliminating the need to make changes to all attributes (Fiorentini, Kinchla and Nolden, 2020).

A summary of the JAR scale data was obtained by counting the number of panel members who selected each scale category as well calculating the corresponding percentage for each category. The two ''too little'' and two ''too much'' categories were combined to streamline the presentation of results; instead of displaying five results for the JAR scale, only three percentages were presented, e.g., combining the categories of “somewhat too high” and “much too high”, into one category, for all results (Narayanan *et al.*, 2014). During JAR scaling, a consumer’s overall liking task was also conducted, to investigate the samples' overall acceptability. The data from both JAR and consumer’s overall liking task were needed for the determination of penalty analysis (Pagès *et al.*, 2014).

IV. Penalty analysis

Penalty analysis has emerged as the most widely applied technique, for linking the JAR attributes with the consumer’s overall liking task (Pagès *et al.*, 2014). This is a method for determining if those respondents, who find the sample not “just about right” on an attribute rating, also ranked the product lower in the consumer’s overall liking task (Pagès *et al.*, 2014). Furthermore, penalty analysis is a within-sample-analysis and is highly applicable for this type of test.

When evaluating the results for overall liking and penalty analysis, at least 20.0% of consumers must voice an opinion for a specific attribute, to be of consequence for penalty analysis, whether the percentage is ‘’too little’’, ‘’just-about-right’’ or ‘’too much’’ (Popper, 2014). In addition, a mean drop of at least 1.0 (on the nine-point hedonic scale) is required for the modification of a sample to be necessary, as well as a weighted penalty of at least 0.75 (as indicated in red in Table 3.4).

Penalty analysis is conducted on all the JAR attributes, one attribute at a time and, for each attribute, it quantifies the impact of being “too high” or “too low”, on the overall liking results (Pagès *et al.*, 2014). Table 3.4 is an example of the penalty calculations for the aroma of the black bean patty. A product can be improved, even if the attributes do not score very high in the JAR test (Narayanan *et al.*, 2014). If the JAR score is ≥ 20%, the sample can be improved (www.sensorydimensions.com). The attribute must score 75% for the “just about right”-category, to be good enough and needing no more improvements (indicated in red in Table 3.4) (Popper, 2014).

Table 3.4: Example of penalty calculation.

Penalty analysis for aroma strength for black bean patty				
	Respondents (%) (at least 20% is required)	**Ranking on the consumer's overall liking test (1 to 9)**	**Mean Drop (>1 required)**	**Weighted Penalty (>0.20 required)**

Too little	30.6	5.96	1.26	0.39
JAR	58.8	7.22		
Too much	10.6	5.67	1.55	0.16
Penalty (mean drop) calculation: (>1.0 needed for product improvement)				
Mean drop for "too little" = 7.22 – 5.96 = 1.26				
Mean drop for "too much" = 7.22 – 5.67 = 1.55				
Weighted penalty calculation: (at least 0.20 needed for product improvement)				
Weighted penalty for "too little" = 1.26 x 0.306 = 0.39				
Weighted penalty for "too much" = 1.55 x 0.106 = 0.16				

V. Standardised difference

A standardised difference measures the strength of an attribute's effect and allows the effect to be ranked and classified (Zhang, 2009). Table 3.5 shows how the standardised mean should be classified, in terms of strength (Zhang, 2011). In this way, it can be better understood how an attribute affects a product's acceptance.

Table 3.5: Standardised difference classification.

Effect Subtype	Limits for standardised difference
Extremely strong	SSMD ≥ 5
Very strong	5 > SSMD ≥ 3
Strong	3 > SSMD ≥ 2
Fairly strong	2 > SSMD ≥ 1.645
Moderate	1.645 > SSMD ≥ 1.28
Fairly moderate	1.28 > SSMD ≥ 1
Fairly weak	1 > SSMD ≥ 0.75
Weak	0.75 > SSMD ≥ 0.5
Very weak	0.5 > SSMD ≥ 0.25
Extremely weak	0.25 > SSMD > 0
Zero	SSMD = 0

3.3.3 Data analysis

The data was analysed with the use of the following software programmes: 'R', R libraries – Performance Analytics for correlations; and Excel: xlstat – sensory (NCSS, 2007). The Tukey-HSD test was employed to identify significant differences between the three samples, and these differences were then denoted in the tables using superscripts. Additionally, the analysis of variation (ANOVA) was utilised to examine whether there were any differences in means among different factors. Correlations between the sensory properties were calculated and tested for significance, using the Spearman method. The correlation values indicate the following: 0–0.19 very weak;

0.2–0.39 weak; 0.40–0.59 moderate; 0.6–0.79 strong; and 0.8–1 very strong (Ali, BhaskaBalakireva and Sudheesh, 2019).

3.3.4 Ethical considerations

The study was conducted in accordance with ethical standards, as evidenced by the obtaining of ethical clearance (UFS-HSD2021/0668) from the General/Human Research Ethics Committee (GHREC) at the UFS on 2 August 2021. The ethical clearance certificate is attached in Appendix A. Prior to sensory tastings taking place, respondents were required to complete a consent form (Appendix D), which stipulated all necessary information to ensure their safety and well-being during the study. The consent form contained comprehensive information regarding the study's nature and purpose, as well as important details concerning potential allergens, such as gluten, that may have been present in the products tasted. Furthermore, respondents were informed that their participation was completely voluntary and that they were allowed to withdraw from the study without penalty. Additionally, the respondents were informed that their participation was anonymous, and their personal information would not be disclosed in the findings of the study.

3.4 RESULTS AND DISCUSSION ON JAR PROFILE 1

3.4.1 Nuggets

I. Demographic profile of the consumer panel

The consumer testing for the maize nuggets were conducted on the 22nd of October 2021 on the campus of the University of the Free State. The participants were staff and students, both under- and post-graduate. The demographic profile of the panels for the nuggets are represented in Table 3.6.

Table 3.6: Demographic profile of consumers participating in the overall liking task and JAR profile of the maize nuggets.

Gender	**n=79**	**%**
Male	14	17.7%
Female	65	82.3%
Age	n=79	
≤35	57	72.1%
>35	22	27.9%

The demographic profile of the consumer panel for the nuggets constituted primarily female participants, younger than 35 years of age. Therefore, 82.3% of the respondents were female, with 72.1% being from the age group ≤35 years. Research has indicated that the female gender is more likely to participate in sensory tastings, as women are primarily responsible for food choices in most households (Laureati *et al.*, 2016). The individuals that took part in the sensory for the patties and nuggets were all enthusiasts of plant-based products.

II. Consumers' overall liking task

Table 3.7 summarises the hedonic ranking of the three nugget samples. The hashbrown and maize nuggets had the highest rankings of 6.41 and 6.80, respectively (=like slightly) and they differed significantly ($p \leq 0.05$) from the chickpea sample (5.29 = neither like nor dislike).

Table 3.7: Overall liking task rankings for the three nugget samples.

	Hashbrowns	Chickpea	Maize
Overall liking	$6.41^{b} \pm 1.7$	$5.29^{a} \pm 1.83$	$6.80^{b} \pm 1.57$

Means with different superscripts in the same row differ significantly (p≤0.05).

III. Correlations between the attributes

For the hashbrown, nine correlations, of which four were negative and five were positive, were noted (Table 3.9). The four negative correlations involved overall liking with the following attributes: moderate with aroma (-0.468); weak with appearance (-0.377); moderate with taste (-0.536) and weak with mouthfeel (-0.379). Negative correlations imply that lowering the intensities of the specific modalities, would lead to an increase in overall liking of the sample. For aroma, there were three weak positive correlations: with appearance (0.347); taste (0.247) and mouthfeel (0.211). Appearance had two weak positive correlations with taste (0.361) and mouthfeel (0.285), while taste had a weak correlation with mouthfeel (0.235) (Table 3.8).

Table 3.8: Correlations matrix for the three nugget samples.

Variables	Overall liking	Aroma	Appearance	Taste	Mouthfeel
Overall liking		-0.468 -0.514	-0.377 -0.386	-0.536 -0.467	-0.379
Aroma			0.347 0.267 0.379	0.247 0.428 0.432	0.211
Appearance				0.361 0.360 0.408	0.285
Taste					0.235

Mouthfeel

Values in bold are different from 0 with a significance level (p≤0.05)
Hashbrown; Chickpea; Maize

The chickpea sample had six correlations, including three negative ones and three positive ones. The negative correlations all included overall acceptability: moderate with aroma (-0.514); weak with appearance (-0.386); and moderate with taste (-0.467). The three positive correlations included two, between aroma and appearance (0.267 = weak) and between aroma and taste (0.428 = moderate), as well as one weak correlation between appearance and taste (0.360) (Table 3.8).

The maize sample only had three positive correlations, namely two involving aroma – weak with appearance (0.379) and moderate with taste (0.432). Lastly, appearance was also moderately correlated with taste (0.408) (Table 3.8).

IV. JAR profiles

Figure 3.9 to 3.11 are the JAR profiles of all the nugget samples. The JAR levels (green bars) for all attributes were ≥20.0%, which indicated that these samples were worth developing further.

a) Hashbrown sample:

The JAR percentages for the hashbrown nugget were as follows: aroma (58.0%); appearance (58.0%); taste (62.0%); and mouthfeel (49.0%). Each of the four attributes had only one non-JAR category that was ≥20.0%, all positioned in the ”too much” category. The respondents found the aroma to be too spicy (35.0%), the appearance was too brown (38.0%) the taste too savoury (33.0%) and the mouthfeel too crunchy (44.0%). All the other non-JAR categories, for all the attributes, were <20.0%, indicating that no changes were needed for these categories (Figure 3.9).

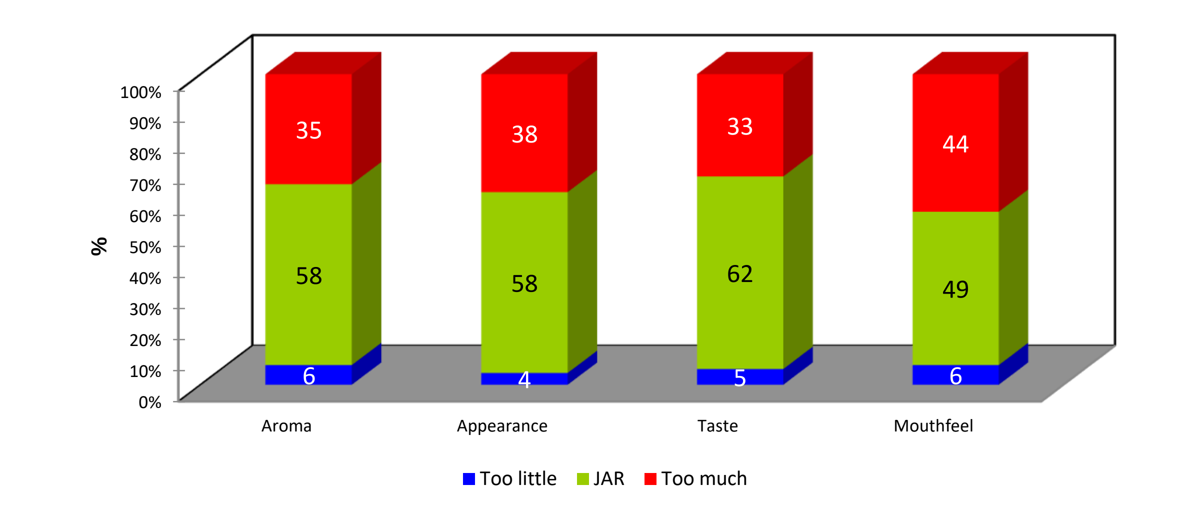

Figure 3.9: JAR profile of the hashbrown sample.

b) Chickpea nugget sample:

For the chickpea nuggets, the JAR percentages were presented as follows: aroma (33.0%); appearance (37.0%); taste (32.0%); and mouthfeel (52.0%). Three of the attributes only had one non-JAR category ≥20.0%, namely too spicy aroma (62.0%), too brown appearance (46.0%) and too savoury taste (56.0%). For mouthfeel, both non-JAR categories were ≥20.0%: too crunchy (25.0%) and too soft (23.0%). All the other non-JAR categories, for all the attributes, were <20.0%, indicating that no changes were needed for these categories (Figure 3.10).

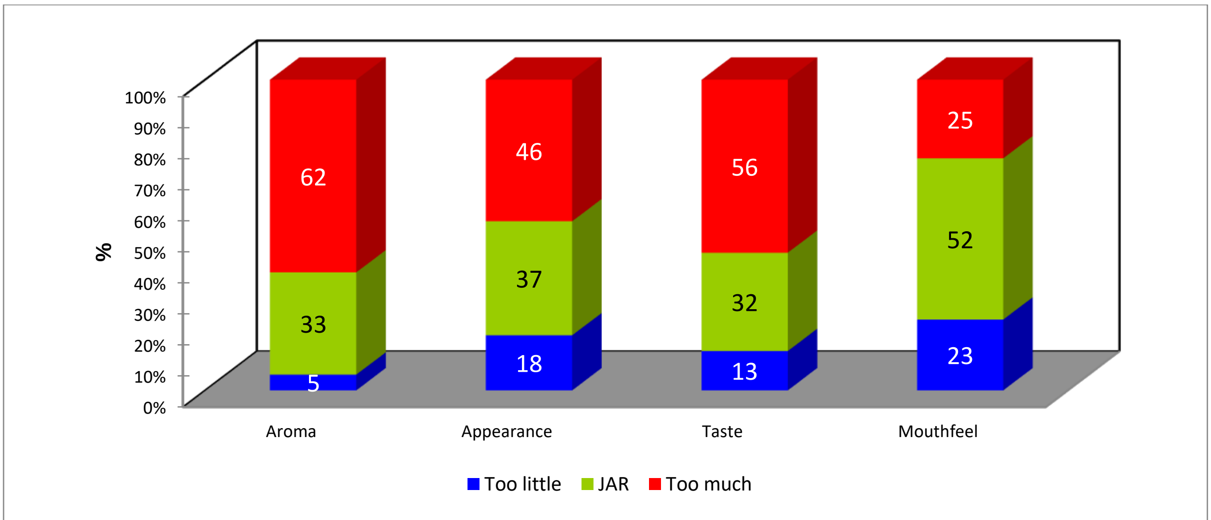

Figure 3.10: JAR profile of the chickpea nugget sample.

c) Maize nugget sample:

The JAR percentages for the maize nugget were as follows: aroma (66.0%); appearance (81%); taste (65.0%); and mouthfeel (54.0%). Aroma had one non-JAR category ≥20.0%, namely the aroma being too bland (23.0%). Taste was also found to be too bland (20.0%). The mouthfeel of the maize nugget sample was found to be too soft (38.0%). All the other non-JAR categories, for all the attributes, were <20.0%, indicating that no changes were needed for these categories (Figure 3.11).

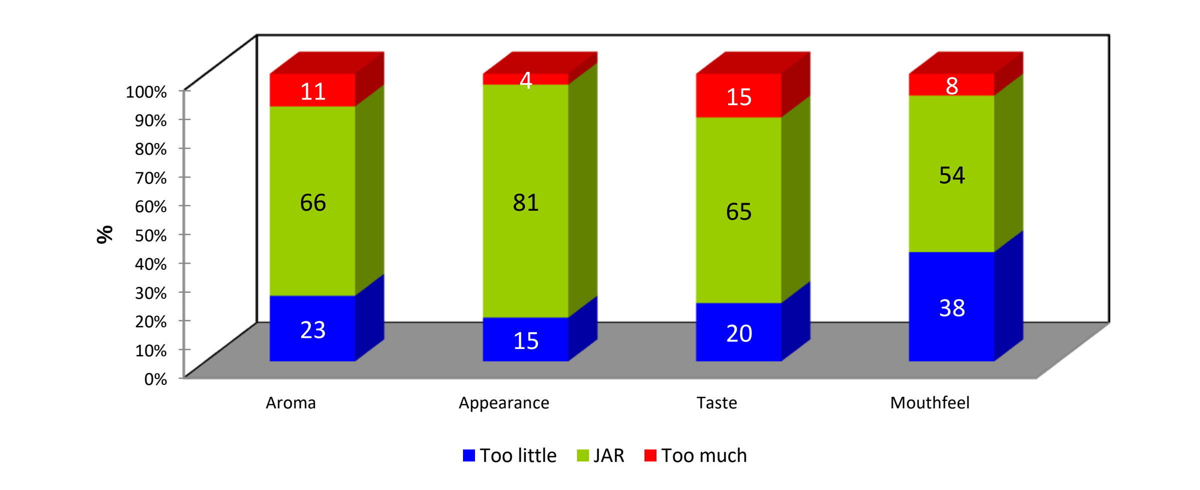

Figure 3.11: JAR profile of the maize nugget.

V. Penalty analysis

Tables 3.11 to 3.13 present the penalty analysis of the three nugget samples.

a) <u>Hashbrown sample:</u>

In Table 3.9, the aroma of the hashbrown had a net penalty of 1.320, which was too high, in addition to having one non-JAR category being ≥20.0%, namely the aroma being too spicy (35.5%), resulting in a mean drop of 1.60 on the hedonic scale. This is the number of rankings the sample lost with the consumers, for being too spicy in the aroma. In addition, the effect of the standardised difference was very strong (3.669) and the p-value very low (0.00), making this attribute significant for the overall liking of the sample. For the appearance of the sample, the net penalty was unacceptably high (1.320), and one of the non-JAR categories, namely ''too high'', had a percentage of 38.0%, resulting in a mean drop of 1.46 on the hedonic scale. The standardised difference had a very strong effect (3.669), and the p-value was low (0.000), implying the significance of the attribute for the overall liking of the sample. The net penalty for taste was also unacceptably high (1.997), in addition to the 'too high' category having a percentage of 32.9%, resulting in a mean drop of 2.20 on the hedonic scale. The standardised difference had an extremely strong effect (6.153), and the p-value was very low (<0.0001), signifying the importance of this attribute for the overall liking of the sample. The net penalty for mouthfeel was 1.580, which was too high, in addition to having the non-JAR category for the mouthfeel being ‘’too little’’ at 44.3%, which resulted in a mean drop of 1.63 on the hedonic scale. The effect of the standardised difference was very strong (4.648) and the p-value very low (<0.0001), also indicting that this attribute was important for the overall liking of the sample.

Table 3.9: Penalty analysis of the hashbrown samples

Variable	Level	%*	Mean (hedonic scale)	Mean drops	p-value	Significant	Penalty	Standardised difference	p-value	Significant
	Too little	6.3	7.20	-0.24			1.320			
Aroma	JAR	58.2	6.96					3.669	0.000	yes
	Too high	35.5	5.36	1.60	<0.0001	yes				
	Too little	3.8	7.00	-0.043						
Appearance	JAR	58.2	6.95				1.320	3.669	0.000	yes
	Too high	38.0	5.50	1.46	0.000	yes				
	Too little	5.1	6.50	0.66						
Taste	JAR	62.0	7.16				1.997	6.153	<0.0001	yes
	Too high	32.9	4.96	2.20	<0.0001	yes				
	Too little	6.3	6.00	1.21						
Mouthfeel	JAR	49.4	7.21				1.580	4.648	<0.0001	yes
	Too high	44.3	5.57	1.63	<0.0001	yes				

b) <u>Chickpea nugget sample:</u>

According to Table 3.10, the chickpea nugget had a high net penalty for aroma (1.802) as well as a non-JAR category ≥20.0%, meaning that the aroma was too bland (62.0%), resulting in a mean drop of 1.87 on the hedonic scale. The standardised difference had a very strong effect (4.627) with a very low p-value (<0.0001), making this attribute significant for the overall liking of the sample. For appearance, the net penalty was too high (1.283), and one of the non-JAR categories, “much too dull”, had a percentage of 45.6%, which resulted in a mean drop of 1.69 on the hedonic scale. The standardised difference was very strong (3.181) and p-value (<0.0001) very low, suggesting the significance of the attribute for the overall liking of the sample. In relation to taste, the net penalty was high (1.915) with one non-JAR category ≥20%, namely being too bland (55.7%), which resulted in a mean drop of 2.06 on the hedonic scale. The standardised difference had a very strong effect (4.941), along with a very low p-value (<0.0001), signifying this attribute’s significance for the overall liking of the sample. In regard to the mouthfeel, the sample had a net penalty of 1.169 and two non-JAR categories ≥ 20 %, namely “too crunchy” (22.8%) and “too soft” (25.3%), resulting in mean drops of 0.97 and 1.35, respectively, on the hedonic scale. The standardised difference had a strong effect (2.983), with a low p-value (0.016), which indicated the significance of mouthfeel for the overall liking of the sample.

Table 3.10: Penalty analysis of the chickpea nugget sample

Variable	Level	%*	Mean (hedonic scale)	Mean drops	p-value	Significant	Penalty	Standardised difference	p-value	Significant
	Too little	5.1	5.50	1.00			1.802			
Aroma	JAR	32.9	6.50					4.627	<0.0001	yes
	Too high	62.0.	4.63	1.87	<0.0001	yes				
	Too little	17.7	5.86	0.25						
Appearance	JAR	36.7	6.10				1.283	3.181	0.002	yes
	Too high	45.6	4.42	1.69	<0.0001	yes				
	Too little	12.7	5.30	1.30						
Taste	JAR	31.6	6.60				1.915	4.941	<0.0001	yes
	Too high	55.7	4.55	2.06	<0.0001	yes				
	Too little	22.8	4.89	0.97	0.131	no				
Mouthfeel	JAR	51.9	5.85				1.169	2.983	<0.004	yes
	Too high	25.3	4.50	1.35	0.016	yes				

c) <u>Maize nugget sample:</u>

According to Table 3.11, the maize nugget had an unacceptable net penalty for aroma (1.380) as well as a non-JAR category ≥20%, namely aroma that was too bland (22.8%), resulting in a mean drop of 1.17 on the hedonic scale. The standardised difference had a very strong effect (4.051), with a low p-value (0.000), rendering this attribute significant for the overall liking of the sample. Although the appearance of this sample had a high net penalty of 1.149, no non-JAR category ≥20.0% and the JAR percentage was 81.0%. The standardised difference was strong (2.644) and had a very low p-value (0.003), suggesting the attribute's significance for the overall liking of the sample. For taste, the sample also had a high net penalty (1.733), with only taste being too bland (20.2%), resulting in a loss of 1.85 on the hedonic scale. The standardised difference had an extremely strong effect (5.495) and a very low p-value (<0.0001), signifying this attribute's significance to the overall liking of the sample. For mouthfeel, the sample had a net penalty of 1.312 and a non-JAR category for mouthfeel being too soft (40.0%), which resulted in a mean drop of 1.10 on the hedonic scale. The standardised difference had a very strong effect (4.041) and a very low p-value (<0.0001), suggesting the attribute’s significance to the overall liking of the sample.

Table 3.11: Penalty analysis of the maize nugget samples

Variable	Level	%*	Mean (hedonic scale)	Mean drops	p-value	Significant	Penalty	Standardised difference	p-value	Significant
	Too little	22.8	6.06	1.21	0.003	yes	1.380			
Aroma	JAR	65.8	7.27					4.051	0.000	yes
	Too high	11.4	5.56	1.71						
	Too little	15.2	6.00	1.02						
Appearance	JAR	81.0	7.10				1.149	2.644	0.010	yes
	Too high	3.8	5.33	1.68	<0.0001	yes				
	Too little	20.2	5.56	1.85						
Taste	JAR	64.6	7.41				1.733	5.495	<0.0001	yes
	Too high	15.2	5.83	1.58						
	Too little	40.0	6.30	1.10	0.001	yes				
Mouthfeel	JAR	54.4	7.40				1.312	4.041	<0.000	yes
	Too high	7.6	5.00	2.40						

VI. Interpretation of the results from the bi-plot chart summary

Figure 3.12 provides a visual representation of the weighted penalties for all the attributes including aroma, appearance, taste and mouthfeel, for the maize nuggets and its two samples. The attributes displayed in the orange box at the top right corner, have surpassed the designated threshold values of 1 for mean drop and 20.0% for the non-JAR percentages. The aforementioned signifies that the re-formulation of the product will be necessary to improve its acceptance. This is because the attributes situated in the box were either ‘too little’ or ‘too much’ and needed its formulation changed or adapted to bring the product to JAR.

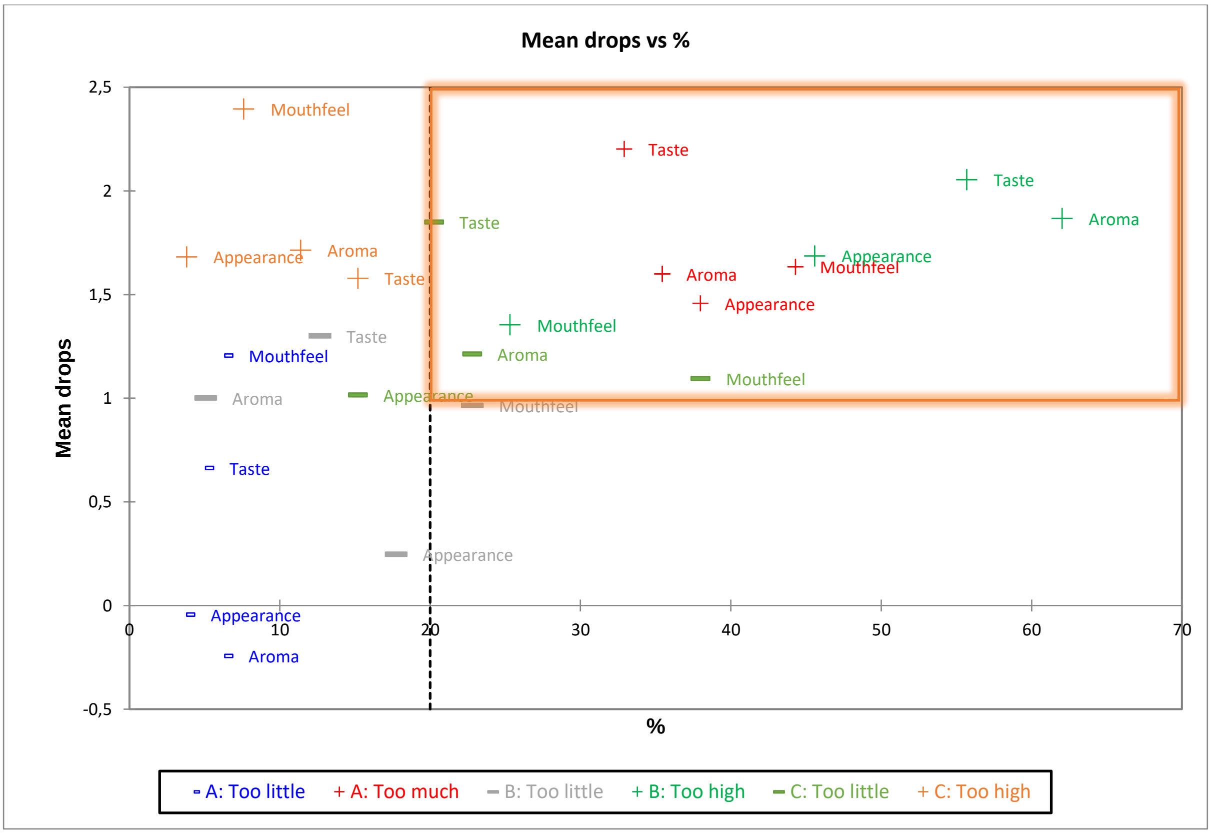

Figure 3.12: Bi-plot for mean drop attributes for the three nugget samples*. *A = Hashbrown; B = Chickpea; C = Maize

According to Figure 3.12, the hashbrown, chickpea and maize nugget samples had a value of more than 1 in the mean drop axis for one or both non-JAR categories, indicating that the formulation for these samples needed improvement. For the hashbrown sample, four non-JAR categories were situated in the top right corner, namely: too spicy aroma; too brown appearance; too savoury taste and too crunchy mouthfeel. The taste attribute had the highest mean drop (2.20) (Table 3.9), indicating that improving the ‘too savoury’ taste, could improve the overall liking of other non-JAR categories as taste had a moderate negative correlation with overall liking. Furthermore, the chickpea sample had four non-JAR categories situated in the top right corner, namely: too spicy aroma; too brown appearance; too savoury taste and too crunchy mouthfeel. Once again, the taste attribute had the highest mean drop (2.06) (Table 3.10), thus indicating that decreasing the too savoury taste would increase the overall liking of the other non-JAR categories as taste had a moderate negative correlation with overall liking. The maize sample had three non-JAR categories in the top right corner, namely: too bland aroma; too bland taste and too soft mouthfeel. The mouthfeel attribute had the highest mean drop of 2.40 (Table

3.11), indicating that improving the crunchiness of maize nugget would move the other non-JAR categories closer to JAR. Moreover, decreasing the blandness of the taste attribute could improve the other non-JAR categories.

3.4.2 Patties

I. Demographic profile of the consumer panel

The consumer testing for the maize patties were conducted on the 21st of October 2021 on the campus of the University of the Free State. The participants were also staff and students, both under- and post-graduate. The demographic profile of the panels for the patties is represented in Table 3.12.

Table 3.12: Demographic profile of consumers participating in the overall liking task and JAR profile of the maize patties.

Gender	**n=83**	**%**
Male	14	16.9
Female	69	83.1
Age	**n=83**	**%**
≤35	64	77.1%
>35	19	22.9%

The demographic profile of the consumer panel for the patties consisted of mostly female participants, younger than 35 years of age who were also enthusiasts of plant-based products. The female respondents constituted 83.1% of the panel members and 77.1% of the respondents were from the age group ≤35 years. As mentioned in *3.4.1 I*, Laureati *et al*. (2016) has indicated that women are more likely to partake in sensory tastings, given that they are typically the ones responsible for selecting food in most households.

II. Consumers' overall liking task

Table 3.13 summarises the hedonic ranking for the three patty samples. The black bean sample had the highest ranking (6.67 = like slightly) for overall liking and differed significantly ($p \leq 0.05$) from the maize patty (5.98 = neither like nor dislike). The chickpea patties overall liking was also situated in the 'like slightly' category, ranking at 6.06.

Table 3.13: Overall liking task rankings for the three patty samples.

Attribute	**Black bean**	**Chickpea**	**Maize**

Overall liking	$6.67^{b} \pm 1.40$	$6.06^{ab} \pm 1.74$	$5.98^{a} \pm 1.93$

Means with different superscripts in the same row differed significantly ($p \leq 0.05$).

III. Correlations between attributes

Table 3.14 depicts the correlation coefficients for the relationship between independent and dependent variables, for all three patty samples. Four positive correlations were found for black bean patty, of which three were weak and one was moderate (Table 3.14). Overall liking had a weak positive correlation with appearance (0.245). Aroma had three positive correlations: moderate with appearance (0.403); weak with taste (0.226); and weak with mouthfeel (0.302).

The chickpea sample showed two negative correlations (Table 3.14), one being weak and one being moderate. Overall liking had a weak negative correlation with aroma (-0.232) and a moderate negative correlation with taste (-0.431). Both correlations implied that overall liking for the sample would increase, if aroma and taste attributes were addressed, and lowered in their modalities, moving their percentages toward the JAR section.

Table 3.14: Correlation matrix for the three patty samples.

Variables	Overall liking	Aroma	Appearance	Taste	Mouthfeel
Overall liking		-0.232 -0.239	0.245 -0.357	-0.431 -0.260	-0.524
Aroma			0.403	0.226 0.328	0.302
Appearance				0.214	
Taste					
Mouthfeel					

Highlighted values are different from 0, with a significance level ($p \leq 0.05$).

Blackbean; Chickpea; Maize

For the maize sample, six correlations were observed (Table 3.14). Overall liking had four negative correlations: weak with aroma (-0.239); weak with appearance (-0.357); weak with taste (-0.260); and moderate with mouthfeel (-0.524). These results indicated that the overall liking of the sample would increase, if the intensity of the sensory modalities were decreased. Taste had two weak positive correlations, with aroma (0.328) and appearance (0.214), indicating that an increase in aroma and appearance would also increase the percentage of taste, toward being JAR.

IV. JAR profile

Figure 3.13 to 3.15 shows the JAR profile of the three patty samples. The JAR levels (green bars) for all attributes were ≥20.0%, which indicated that this sample was worth developing further.

a) Black bean patty sample:

The JAR percentages, for the black bean patty, were as follows: aroma (59.0%); appearance (32.0%); taste (58.0%); and mouthfeel (53%). Aroma only had one non-JAR attribute ≥20.0%, namely too bland aroma (31.0%). Appearance had 65.0% for the appearance being too dull. Taste was either too savoury or bland, as indicated by 22.0% and 20.0% of the consumers, respectively. The mouthfeel was found to be too gritty, by 28.0% of the consumers. All the other non-JAR categories, for all the attributes were <20.0%, indicating that no changes were needed for these cases (Figure 3.13).

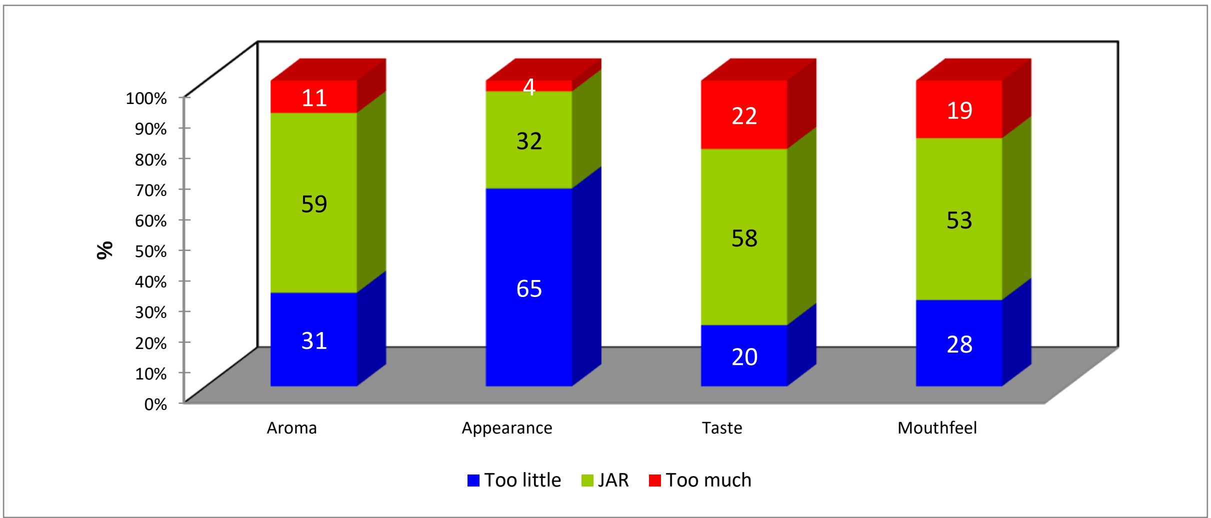

Figure 3.13: JAR profile of the black bean patty sample.

b) Chickpea patty sample:

The chickpea patty's JAR percentages were as follows: aroma (51.0%); appearance (54.0%); taste (35.0%) and mouthfeel (53.0%). There were only three non-JAR categories ≥20.0% for aroma, appearance and taste: too strong aroma (44.0%); too light appearance (36.0%) and too savoury taste (59.0%). For mouthfeel, both non-JAR categories were ≥20.0%: too gritty (20.0%); and too smooth (27.0%). All the other non-JAR categories, for all the attributes, were <20.0%, indicating that no changes were needed for these categories (Figure 3.14).

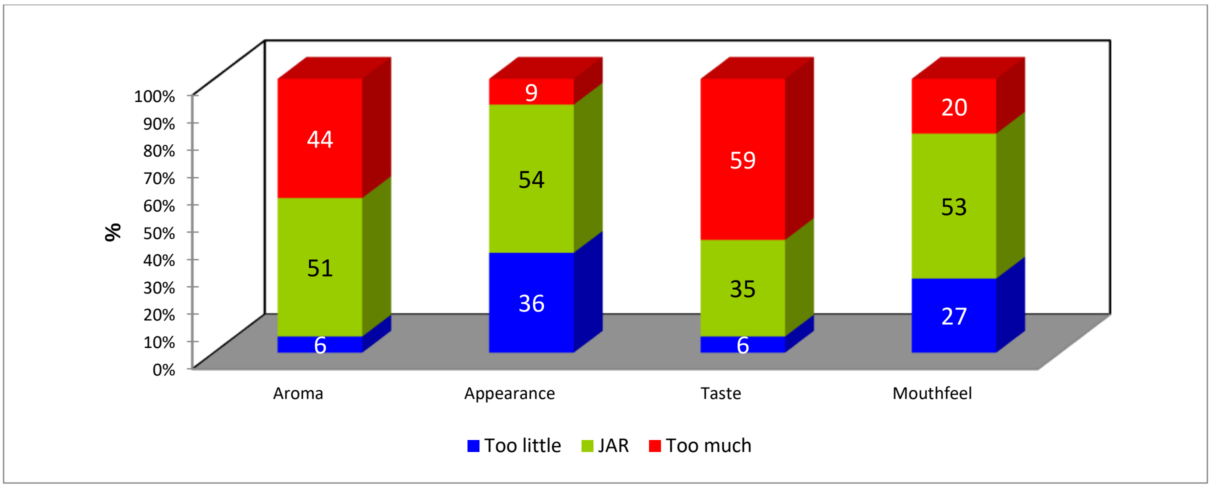

Figure 3.14: JAR profiles of the chickpea patty sample.

c) <u>Maize patty sample:</u>

The appearance of the maize patty came the closest to the JAR percentage of 75.0%, namely 73.0%. The JAR percentages for the other attributes were as follows: aroma (56.0%); taste (51.0%); and appearance (42.0%). All the attributes had percentages for the too much category: aroma (34.0%); appearance (26.0%); taste (29.0%); and mouthfeel (56.0%). Only taste had a percentage ≥20.0% for the too little category, namely 20.0%. All the other non-JAR categories, for all the attributes, were <20.0%, indicating that no changes were needed for these categories (Figure 3.15).

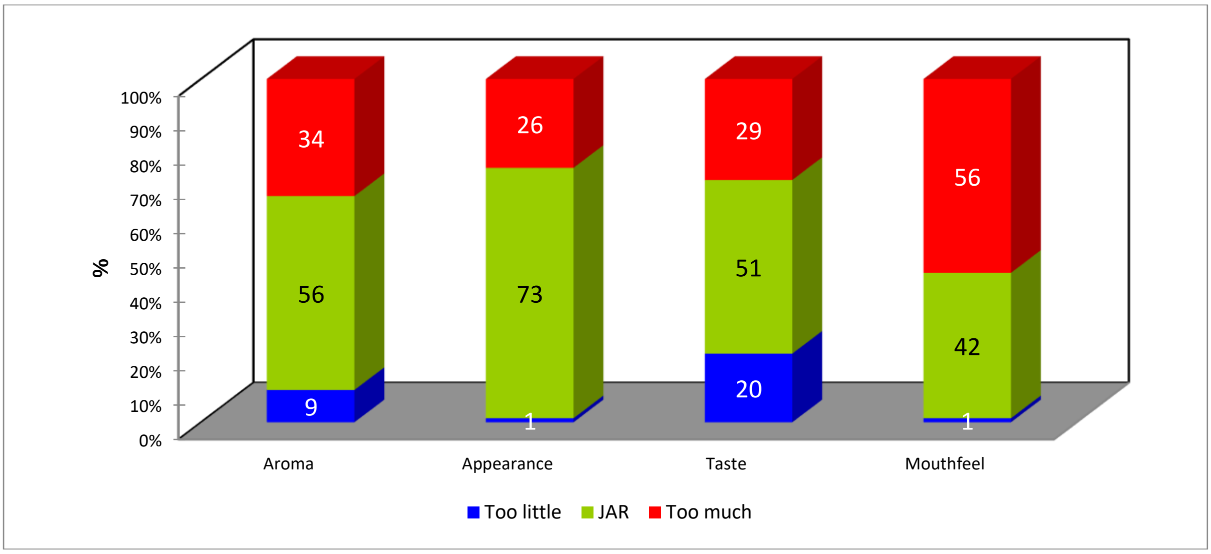

Figure 3.15: JAR profiles of the maize patty sample.

V. Penalty analysis

Tables 3.16 to 3.18 shows the penalty analysis of the three patty samples.

a) <u>Black bean patty sample:</u>

Table 3.15 is the summary of the penalty analysis for the black bean patty. The aroma of this sample had an unacceptable net penalty (1.334), along with one non-JAR category ≥20.0% ('too bland' = 30.6%) and a mean drop of 1.26. The standardised difference had a very strong effect (4.873), and the p-value was very low (<0.0001), indicating that the aroma was significant for the overall liking of the sample. The net penalty for appearance was unacceptably high, at 0.971, and the percentage of the non-JAR category, 'too little' was extremely high (64.7%), resulting in a mean drop of almost 1 (0.93) on the hedonic scale. The effect of the standardised difference was very strong (3.128) and the p-value low (0.002), indicating that the appearance was significant for the overall liking of this sample. The taste had a net penalty of 1.501, which was again unacceptable. In addition, both non-JAR categories, namely the sample being too salty (22.4%), as well as being too bland (20.0%), were ≥ 20.0%, resulting in mean drops of 1.36 and 1.66, respectively, on the hedonic scale. The standardised difference had an extremely strong effect (5.732) and a very low p-value (<0.0001), indicating the significance of taste for the overall liking of the sample. Mouthfeel also had a net penalty that was unacceptable, namely 1.361. The non-JAR category of mouthfeel was too smooth, at 28.3%, and it also had a mean drop of 1.23. The effect of the standardised difference was extremely strong (5.093) and the p-value very low (<0.0001), showing the significance of the mouthfeel for the overall liking of the sample.

Table 3.15: Penalty analysis of black bean patty

Variable	Level	%*	Mean (hedonic scale)	Mean drops	p-value	Significant	Penalty	Standardised difference	p-value	Significant
	Too little	30.6	5.96	1.26	<0.0001	yes	1.334			
Aroma	JAR	58.8	7.22					4.873	<0.0001	yes
	Too high	10.6	5.67	1.55						
	Too little	64.7	6.40	0.93	0.004	yes				
Appearance	JAR	31.8	7.33				0.971	3.128	0.002	yes
	Too high	3.5	5.67	1.67						
	Too little	20.0	5.65	1.66	<0.0001	yes				
Taste	JAR	57.6	7.31				1.501	5.732	<0.0001	yes
	Too high	22.4	5.95	1.36	0.000	yes				
	Too little	28.3	6.08	1.23	0.000	yes				
Mouthfeel	JAR	52.9	7.31				1.361	5.093	<0.0001	yes
	Too high	18.8	5.75	1.56						

b) Chickpea patty sample:

Table 3.16 is the summary of the penalty analysis for the chickpea sample. The aroma had an unacceptable net penalty (1.387). In addition, at 43.5%, the aroma was regarded as too strong, resulting in a mean drop of 1.23 on the 9-point hedonic scale. The standardised difference had a very strong effect (3.983) and a low p-value of 0.000, showing the significance of aroma for the overall liking of this sample. For appearance, the net penalty was also unacceptable, at 1.246. A mean drop of 1.02 was observed for the sample being too light in colour (36.5%). The effect of the standardised difference was very strong (3.500) and the p-value very low (0.001), thus, indicating that this attribute was significant for the overall liking of the sample. The taste attribute also had an unacceptable net penalty of 1.712. In addition, the taste, being too strong, was indicated by 58.8% of the consumers, resulting in a mean drop of 1.71, while only 35.3% indicated that it was JAR. The effect of the standardised difference was very strong (4.886) and the p-value was very low (<0.0001), indicating the significance of the taste on the overall liking of the sample. The net penalty for mouthfeel was unacceptable (1.858), in addition to both non-JAR categories being ≥20.0%: 27.1% for mouthfeel being too smooth, resulting in a mean drop of 2.06; and 20.0% for it being too gritty, resulting in a mean drop of 1.58. The standardised difference had an extremely strong effect (5.872) and the p-value was very low (<0.0001), denoting the significance of the mouthfeel on the overall liking of the sample.

Table 3.16: Penalty analysis of chickpea patty

Variable	Level	%*	Mean (hedonic scale)	Mean drops	p-value	significant	Penalty	Standardised difference	p-value	significant
	Too little	5.9	4.20	2.54						
Aroma	JAR	50.6	6.74				1.387	3.983	0.000	yes
	Too high	43.5	5.51	1.23	0.001	yes				
	Too little	36.5	5.61	1.02	0.008	yes				
Appearance	JAR	54.1	6.63				1.246	3.500	0.001	yes
	Too high	9.4	4.50	2.13						
	Too little	5.9	5.40	1.77						
Taste	JAR	35.3	7.17				1.712	4.886	<0.0001	yes
	Too high	58.8	5.46	1.71	<0.0001	yes				
	Too little	27.1	4.87	2.06	<0.0001	yes				
Mouthfeel	JAR	52.9	6.93				1.858	5.782	<0.0001	yes
	Too high	20.0	5.35	1.58	0.001	yes				

c) <u>Maize patty sample:</u>

Table 3.17 is the summary of the penalty analysis for the maize patty. The aroma of this sample had an unacceptable net penalty (0.909). In addition to 34.1% of consumers indicating that the aroma was too strong, the mean drop was 1.02 on the hedonic scale. The effect of the standardised difference was strong (2.206) and the p-value low (0.030), thereby indicating the significance of the aroma on the overall liking of the sample. For appearance, the net penalty was also unacceptable, at 1.311, in addition to the appearance being too brown (25.9%), resulting in a mean drop of 1.40 on the hedonic scale**.** The standardised difference had a strong effect (2.908) and the p-value was low (0.005); thus, appearance was significant for the overall liking of the sample. The net penalty for taste was also unacceptable (2.118) and both non-JAR categories were ≥20.0%: too bland (20.0%) and too salty (29.4%), resulting in mean drops on the hedonic scale of 1.64 and 2.45, respectively. The standardised difference's effect was extremely strong (6.042) and the p-value very low (<0.0001), thereby signifying that the taste was very important for the overall liking of the sample. The net penalty for mouthfeel was unacceptable (1.858). In addition, the non-JAR category of the sample's mouthfeel, being too gritty (56.5%), was higher than the JAR percentage of 42.2. This resulted in a mean drop of 1.61 on the hedonic scale. The effect of the standardised difference was very strong (4.247) and the p-value very low (<0.0001), indicating the significance of the mouthfeel on the overall liking of the sample.

Table 3.17: Penalty analysis of maize patty

Variable	Level	%*	Mean (hedonic scale)	Mean drops	p-value	Significant	Penalty	Standardised difference	p-value	Significant
	Too little	9.4	5.88	0.52			0.909			
Aroma	JAR	56.5	6.40					2.206	0.030	yes
	Too high	34.1	5.38	1.02	0.023	yes				
	Too little	1.2	7.00	-0.65						
Appearance	JAR	72.9	6.36				1.311	2.908	0.005	yes
	Too high	25.9	4.96	1.40	0.003	yes				
	Too little	20.0	5.41	1.64	0.002	yes				
Taste	JAR	50.6	7.05				2.118	6.042	<0.0001	yes
	Too high	29.4	4.60	2.45	<0.0001	yes				
	Too little	1.2	4.00	2.94						
Mouthfeel	JAR	42.4	6.94				1.858	4.247	<0.0001	yes
	Too high	56.5	5.33	1.61	<0.0001	yes				

VI. Interpretation of results from the bi-plot chart summary

Figure 3.16 provides the weighted penalties for the maize patty and its two samples. The attributes encapsulated in the orange box have mean drops of 1 and more as well as non-JAR categories >20.0%. As per Figure 3.16, all the samples had a mean drop of 1 or more as well as a non-JAR category above 20.0%. The black bean sample had four categories in the top right corner, namely: too bland aroma; too savoury taste; too bland taste and too smooth mouthfeel. The too bland taste attribute had the highest mean drop of 1.66 (Table 3.15), indicating that improving the formulation of the black bean patty to be more savoury, would improve the JAR levels of the other categories. For the chickpea sample, five categories were situated in the top right corner, namely: too spicy aroma; too dull appearance; too savoury taste; too smooth mouthfeel and too gritty mouthfeel. The too smooth mouthfeel had the highest mean drop (2.06) (Table 3.16); however, the too savoury taste category was highest non-JAR category, indicating that lowering the intensity of the taste would improve the overall liking of the product as there was a moderate negative correlation with taste and overall liking. The maize sample had five categories in the top right corner, namely: too spicy aroma; too brown appearance; too savoury taste; too bland taste and too gritty mouthfeel. The taste category had the highest mean drop of 2.45 (Table 3.17) with the mouthfeel having moderate negative correlation between overall liking, indicating that a decrease in the mouthfeel’s crispiness would increase the overall liking of the product.

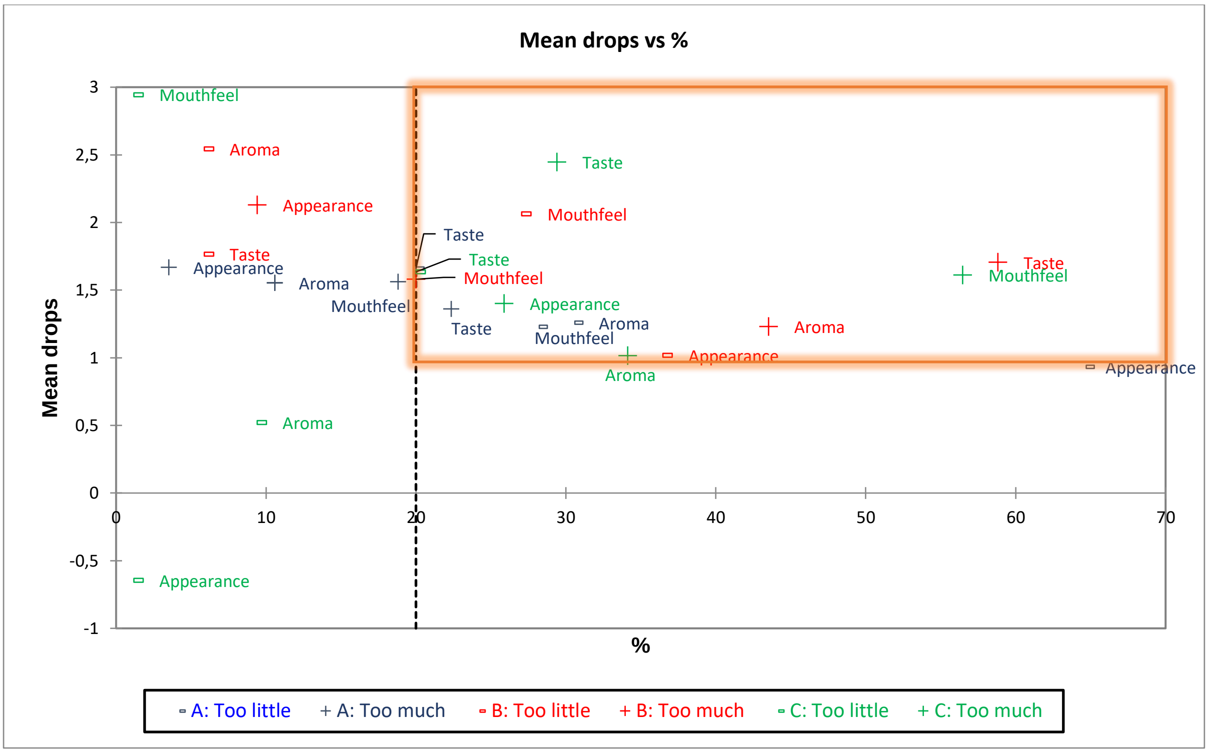

Figure 3.16: Bi-plot for mean drop attributes for three patty samples*. *A = Black bean; B = Chickpea ; C = Maize

3.4.3 Chips

I. Demographic profile of the consumer panel

The consumer testing for the maize chips were conducted on the 20th of October 2021 on the campus of the University of the Free State. The participants consisted of 80 staff and students, both under- and post-graduate. It should be noted, however, that detailed demographic information such as gender and age were not collected for the first panel of the maize chip sensory panel as the participants were regular consumers of snack foods.

II. Consumers' overall liking task

Table 3.18 shows that the deep-fried chip had the highest ranking (7.47 = like moderately) for overall liking and differed significantly ($p \leq 0.05$) from the air fried 1 chip (5.43 = neither like or dislike) and the air fried 2 chip (5.48).

Table 3.18: Overall liking rankings for the three chip samples ($p \leq 0.05$).

	a) Air fried 1	b) Air fried 2	c) Deep-fried
Overall liking	$5.43^a \pm 1.77$	$5.48^a \pm 1.69$	$7.47^b \pm 1.06$

Means with different superscripts in the same row differ significantly (p≤0.05).

III. Correlations between attributes

For the air fried chip 1, four correlations were observed. The overall liking had two negative correlations: moderate with appearance (-0.433); and moderate with taste (-0.508). These results indicated that the overall liking of the air fried 1 chip would increase, if the intensity of the attributes would be decreased. The taste had two weak positive correlations, with aroma (0.269) and appearance (0.250), indicating that improving the appearance would directly increase the JAR percentage of the taste (Table 3.19).

Table 3.19: Correlations matrix for the three chip samples

Variables	Overall liking	Aroma	Appearance	Taste	Mouthfeel
Overall liking			-0.433 -0.278	-0.508 -0.371 -0.269	
Aroma			0.298	0.269 0.271	0.271
Appearance				0.250	
Taste					0.367
Mouthfeel					

Values in bold are different from 0 with a significance level (p≤0.05).

Air fried 1; Air fried 2; Deep-fried

Air fried chip 2 showed two negative correlations (Table 3.19), both being weak. Overall liking had a weak negative correlation with both appearance (-0.278) and taste (-0.371). Both of these correlations suggested that the overall liking of this sample would increase, if the intensity of the appearance and taste attributes were lowered. Furthermore, taste had one weak positive correlation with mouthfeel (0.367), indicating that improving the taste of the air fried chip 2 would increase the JAR percentage of the mouthfeel of the chip.

Three positive weak correlations were identified for the deep-fried chips (Table 3.19). Overall liking had a weak negative correlation with taste (-0.269). Aroma had three positive correlations: weak with appearance (0.298), weak with taste (0.271) and weak with mouthfeel (0.271). According to the results of the correlation analysis, increasing any attribute's JAR percentage, increases its overall acceptability.

IV. JAR profiles

Figure 3.17 to 3.19 shows the JAR profile of all three chip samples. The JAR levels (green bars) for all attributes were ≥20.0%, which indicated that these samples were worth further development.

a) Air fried chip 1 sample:

The JAR percentages for the first air fried chip were as follows: aroma (41.0%); appearance (35.0%); taste (28.0%); and mouthfeel (49.0%). Aroma had two non-JAR categories that were ≥20.0%, namely too much corn aroma (38.0%) and too little corn aroma (22.0%). Appearance had only one non-JAR category ≥20.0, namely too brown appearance (62.0%). Taste was found to be too savoury by 59.0% of the panelists. For mouthfeel, both non-JAR categories were ≥20.0%: too crispy (27.0%); and too soft (24.0%). All the other non-JAR categories, for all the attributes, were <20.0%, indicating that no changes were needed for these categories (Figure 3.17).

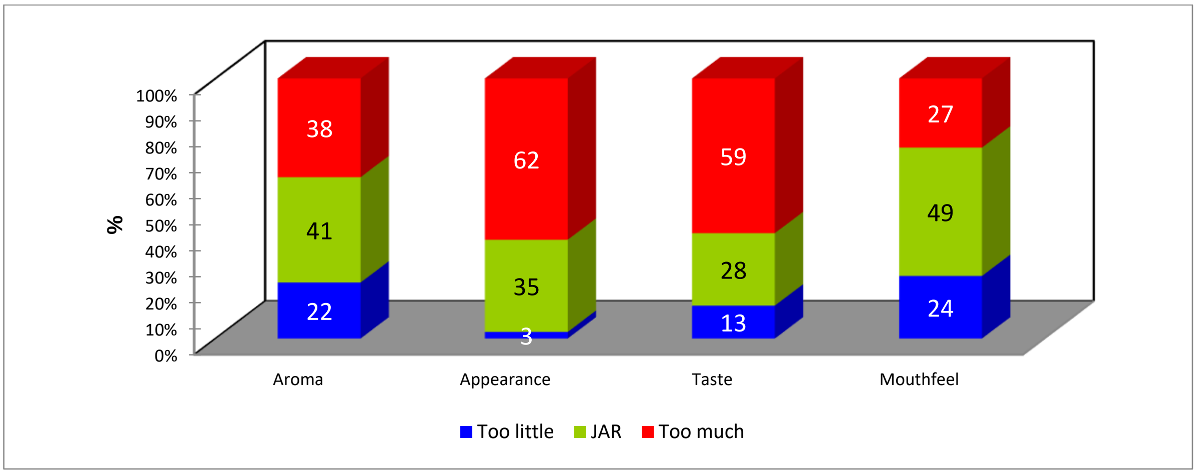

Figure 3.17: JAR profile of air fried chip 1.

b) Air fried chip 2 sample:

The JAR percentages for the second air fried chip were as follows: aroma (39.0%); appearance (51.0%); taste (29.0%); and mouthfeel (30.0%). For aroma, both non-JAR categories were ≥20.0%: too much corn aroma (39.0%); and too little corn aroma (22.0%). The appearance had only one non-JAR category ≥20.0%, with 48.0% of the consumers agreeing that the chip was too brown. Taste also had one non-JAR category, with 62.0% of the consumers agreeing that the chip tasted too savoury. With regards to mouthfeel, both non-JAR categories were ≥20.0%: too crispy (49.0%); and too soft (20.0%). All the other non-JAR categories, for all the attributes, were <20.0%, indicating that no changes were needed for these categories (Figure 3.18).

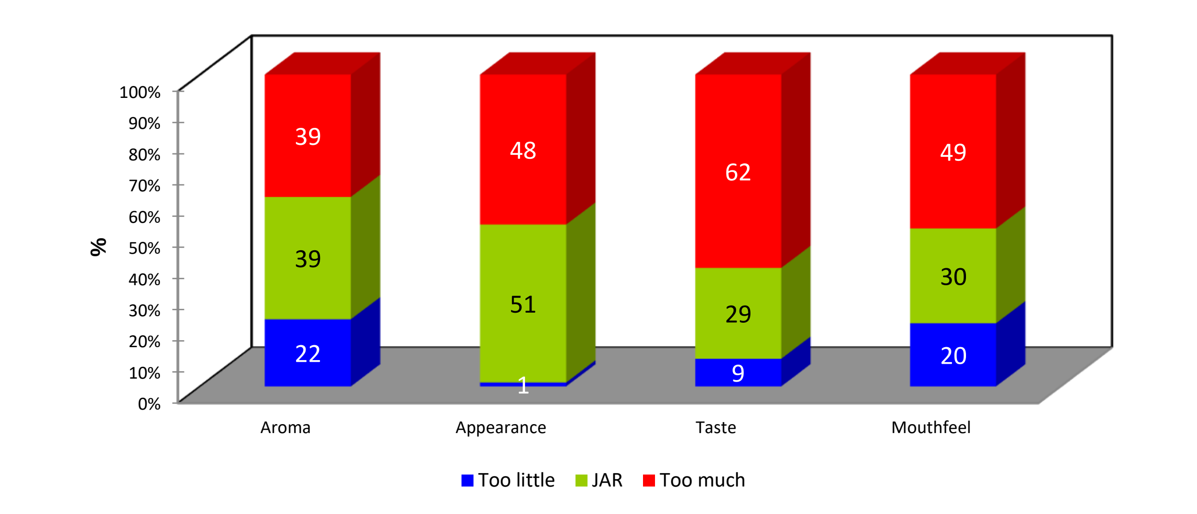

Figure 3.18: JAR profile of air fried chip 2.

c) <u>Deep-fried chip sample:</u>

For the deep-fried chip, the JAR percentages are revealed in the following manner: aroma (73.0%); appearance (52.0%); taste (76.0%); and mouthfeel (84.0%). Aroma had only one non-JAR category ≥20.0%, with 22.0% of the consumers agreeing that it had too little corn aroma. Appearance also had one non-JAR category: much too dull in colour (29.0%). The non-JAR categories for taste and mouthfeel were <20.0%, indicating that no changes were needed for these attributes (Figure 3.19).

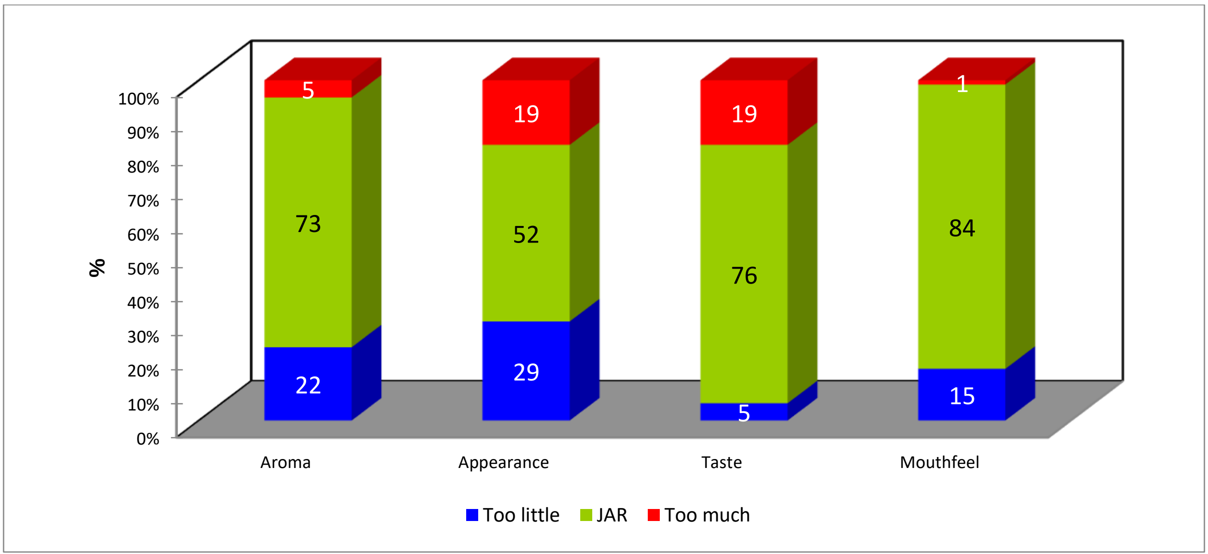

Figure 3.19: JAR profiles of the deep-fried chip.

V. Penalty analysis

Tables 3.20 to 3.22 show the penalty analysis for the three chip samples.

a) <u>Air fried chip 1 sample:</u>

Table 3.20 is the summary of the penalty analysis for air fried 1 chip. The aroma of this sample had a high net penalty (1.789), along with both of the non-JAR categories being ≥20.0%. The sample had too little oily, corn or starch aroma (21.5%), while it was also found that the aroma was too oily, corny or starchy (38.0%), resulting in mean drops of 1.85 and 1.77, respectively. The standardised difference had an extremely strong effect (5.105) and a very low p-value (<0.0001), thereby signifying that aroma was significant for the overall liking of the sample. The appearance of the sample also had an unacceptable net penalty (1.823) and the non-JAR category 'much too dull' was extremely high (62.0%), resulting in a mean drop of 1.79 on the hedonic scale. The effect of the standardised difference was extremely strong (5.023), with a very low p-value (<0.0001), suggesting that this attribute was very important for the overall liking of the sample. The taste of the sample had a net penalty of 2.301, which rendered it unacceptable. The non-JAR category 'much too bland' was high (59.5%), resulting in a mean drop of 2.39 on the hedonic scale. The standardised difference was extremely strong (6.375) and had a very low p-value (<0.0001), indicating the significance of taste for the overall liking of the sample. The mouthfeel of the sample had a net penalty of 1.024, as well as both of the non-JAR categories being ≥20.0%. The sample was too crunchy (24.0%) and also too soft (26.6%), resulting in mean drops of 1.05 and 1.00 respectively, on the hedonic scale. The effect of the standardised difference was strong (2.675), with a low p-value (<0.0009). It showed the significance of the mouthfeel for the overall liking of the sample.

Table 3.20: Penalty analysis of air fried chip 1

Variable	Level	%*	Mean (hedonic scale)	Mean drops	p-value	Significant	Penalty	Standardised difference	p-value	Significant
	Too little	21.5	4.65	1.85	0.000	yes	1.789			
Aroma	JAR	40.5	6.50					5.105	<0.0001	yes
	Too high	38.0	4.73	1.77	<0.0001	yes				
	Too little	2.5	4.00	2.61						
Appearance	JAR	35.4	6.61				1.823	5.023	<0.0001	yes
	Too high	62.0	4.82	1.79	<0.0001	yes				
	Too little	12.7	5.20	1.89						
Taste	JAR	27.9	7.09				2.301	6.375	<0.0001	yes
	Too high	59.5	4.70	2.39	<0.0001	yes				
	Too little	24.0	4.90	1.05	0.077	no				

Mouthfeel	JAR	49.4	5.95				1.024	2.675	<0.009	yes
	Too high	26.6	4.95	1.00	0.087	no				

b) <u>Air fried chip 2 sample:</u>

Table 3.21 is the summary of the penalty analysis for air fried 2 chip. The aroma of the sample had a net penalty of 0.907, while both of the non-JAR categories were ≥20.0%, namely being too oily, corny or starchy (21.5%), as well as being too low in oily, corn or starch aroma (39.2%); the too much category's results led to a mean drop of 1.21 on the hedonic scale. The standardised difference had a fairly strong effect (2.406) and a low p-value (0.019), thereby indicating the significance of the attribute for the overall liking of the sample. The appearance of the sample had a net penalty of 0.950, while the non-JAR category 'too dull' was very high (48.1%), resulting in a mean drop of 0.90. The effect of the standardised difference was fairly strong (2.594) and the p-value (0.011) low, suggesting that this attribute was significant for the overall liking of the sample. The taste of the sample had a high net penalty of 1.652. In addition, the non-JAR category 'much too bland' was extremely high (62.0%), resulting in a mean drop of 1.63 on the hedonic scale. The standardised difference was very strong (4.397) and the p-value was very low (<0.0001), showing the significance of the attribute for the overall liking of the sample. The mouthfeel of the sample had a high net penalty (1.164) as well as both non-JAR categories ≥20.0%; being too crispy (20.3%) and too soft (49.3%), resulting in mean drops of 0.92 and 1.27, respectively, on the hedonic scale. The standardised difference was fairly strong (2.960) and the p-value low (0.004), presenting the significance of the mouthfeel on the overall liking of the sample.

Table 3.21: Penalty analysis of air fried chip 2

Variable	Level	%*	Mean (hedonic scale)	Mean drops	p-value	Significant	Penalty	Standardised difference	p-value	Significant
	Too little	21.5	4.82	1.21	0.044	yes	0.907			
Aroma	JAR	39.3	6.03					2.406	0.019	yes
	Too high	39.2	5.29	0.74	0.182	no				
	Too little	1.3	3.00	3.00						
Appearance	JAR	50.6	6.00				0.950	2.594	0.011	yes
	Too high	48.1	5.05	0.90	0.017	yes				
	Too little	8.9	4.86	1.80						
Taste	JAR	29.1	6.65				1.652	4.397	<0.0001	yes
	Too high	62.0	5.02	1.63	0.000	yes				
	Too little	20.3	5.38	0.92	0.190	no				
Mouthfeel	JAR	30.4	6.29				1.164	2.960	0.004	yes
	Too high	49.3	5.03	1.27	0.009	yes				

c) Deep-fried chip sample:

Table 3.22 is the summary of the penalty analysis of the deep-fried chip. The aroma of the sample had a net penalty of 0.314, which was acceptable (<0.750). The non-JAR category ‘much too oily, corny or starchy’ was 21.5%, which was ≥20.0%; however, it only resulted in a meaningless mean drop of only 0.26 on the hedonic scale. The effect of the standardised difference was moderate (1.164) and had a high p-value of 0.248, indicating that this attribute was not significant in the overall liking of the sample. The appearance of the sample had an acceptable net penalty of 0.040. The non-JAR category ‘much too brown’ was 29.1%, resulting in a meaningless mean drop of only 0.10 on the hedonic scale. The effect of the standardised difference was fairly weak (0.168), with a high p-value (0.867), therefore indicating that this attribute was not significant for the overall liking of the sample. The taste of the sample had a net penalty of 0.547, which was considered acceptable and had no non-JAR category ≥20.0%. The standardised difference was fairly strong (1.999) and had a low p-value (0.049), indicating the taste’s significance on the overall liking of the sample. The mouthfeel of the sample had a net penalty of 0.376, which was acceptable, with no non-JAR categories ≥20.0%. The standardised difference was moderate (1.173) and had a high p-value (0.244), therefore indicating that this attribute was not significant in the overall liking of the sample.

Table 3.22: Penalty analysis of the deep-fried chip

Variable	Level	%*	Mean (hedonic scale)	Mean drops	p-value	Significant	Penalty	Standardised difference	p-value	Significant
	Too little	21.5	7.29	0.26	0.375	no	0.314			
Aroma	JAR	73.4	7.55					1.164	0.248	no
	Too high	5.1	7.00	0.55						
	Too little	29.1	7.39	0.10	0.735	no				
Appearance	JAR	51.9	7.49				0.040	0.168	0.867	no
	Too high	19.0	7.53	-0.05						
	Too little	5.1	7.75	-0.15						
Taste	JAR	75.9	7.60				0.547	1.999	0.049	yes
	Too high	19.0	6.87	0.73						
	Too little	15.2	7.08	0.45						
Mouthfeel	JAR	83.5	7.53				0.376	1.173	0.244	no
	Too high	1.3	8.00	0.47						

VI. Interpretation of results from the bi-plot chart summary

Figure 3.20 provides the weighted penalties for all three maize chip samples. The attributes within the orange box have mean drops of 1 and more as well as non-JAR categories >20.0%. Figure 3.20 shows that samples air fried chip 1 and 2 both had categories in the top right corner (orange box), indicating that the formulation of these samples needed to be improved to increase the JAR percentages. The air fried 1 sample had six categories in the orange box, namely: too much corn aroma; too little corn aroma; too brown appearance; too savoury taste; too crispy mouthfeel and too soft mouthfeel. The taste category had the highest mean drop (2.39) (Table 3.20) of the above-mentioned attributes as well as a moderate negative correlation with overall liking. Thus, decreasing the intensity of the savoury taste would increase the overall liking of the other non-JAR categories. For the air fried 2 sample, three categories are situated in the orange box, namely: too little corn aroma; too savoury taste and too crispy mouthfeel. The taste category had the highest mean drop (1.80) (Table 3.21) of the three categories in the box as well as a weak positive correlation with overall liking. Therefore, altering the formulation to decrease the savoury taste of the sample, would improve the overall liking of the other non-JAR categories. The maize chip had no categories in the orange box, however the non-JAR 'too dull' category for appearance (orange oval) had the highest percentage of all the categories, thus indicating that yielding a chip with a browner appearance would improve the JAR percentage of the taste attribute.

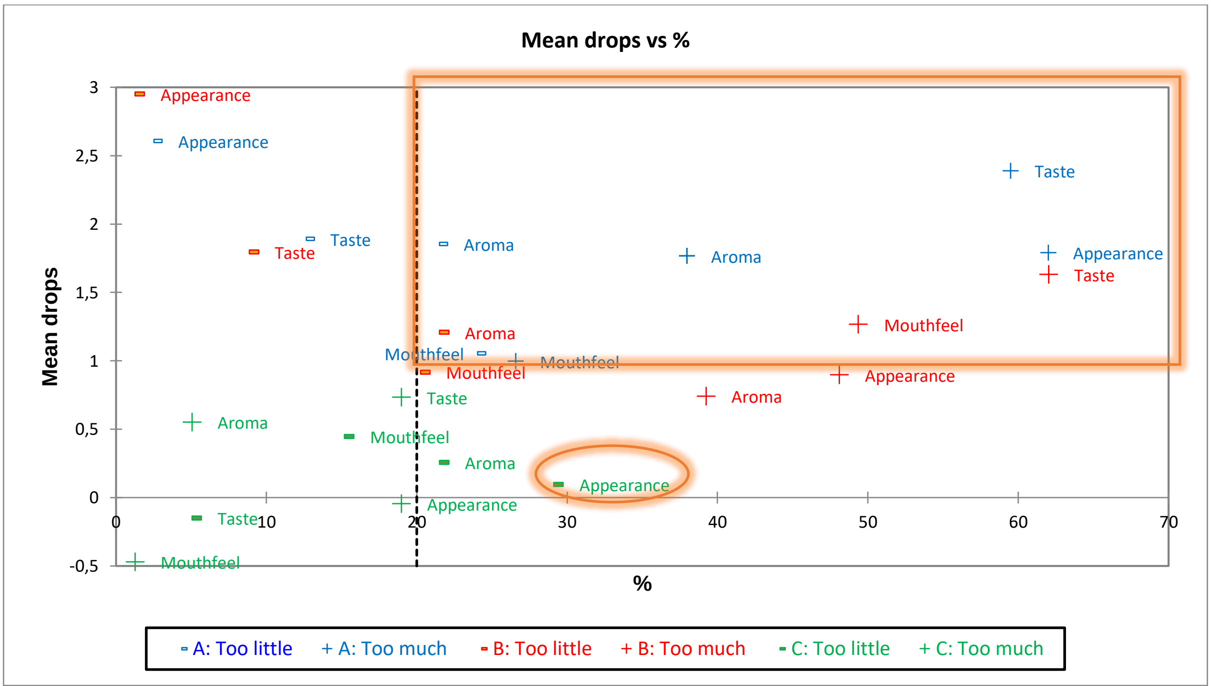

Figure 3.20: Bi-plot for mean drop attributes for the three maize chip samples*. *A = air fried 1; B = air fried 2; C = deep fried.

3.4.4 Conclusion to JAR profile 1

For the first phase, three products were developed and underwent sensory analysis. The aim was to conclude which of the three products the consumers found the most acceptable and whether that product would need improvement, to bring it closer to JAR. The general conclusion for each of the products are outlined as:

I. **Maize nugget:**

The consumer panellists found the nugget unacceptable as well, but the appearance attribute had the highest JAR percentage (81.0%) of all the attributes, for all the samples included in the first JAR test. Nevertheless, the maize nugget outperformed both chickpea nuggets and hashbrowns in terms of their JAR percentages.

II. **Maize patty:**

This product had unacceptable JAR percentages for aroma (56.0%), taste (51.0%) and mouthfeel (42.0%). However, appearance had a close acceptability percentage of 73.0. The maize patty was the product with the lowest consumer acceptability. It must be noted, however, that the maize patty had higher JAR percentages than both the black bean and chickpea patties.

III. **Maize chip:**

The maize chip had three samples, which were all maize, but the cooking methods differed: deep fried; and two air fried chips. The deep-fried chip had the most acceptable JAR percentages. Three of the attributes were above 70.0%: aroma (73.0%); taste (76.0%); and mouthfeel (84.0%). The appearance attribute had an unacceptable JAR percentage of 52.0%, with 29.0% of the panellists finding the appearance much too dull.

By way of conclusion, the product with the highest overall liking was the deep-fried maize chip; nevertheless, the appearance was below consumer acceptability, which requires the improvement of this attribute, to address consumers' need for acceptance.

3.5 RESULTS AND DISCUSSION OF JAR PROFILE 2

3.5.1 Improved chip

I. Product improvement

To address the ‘’too dull in colour’’ appearance attribute, the chip was fried for a slightly longer period (Figure 3.21). Table 3.23 shows the formulation of the improved deep-fried chip. The same technique was used to make the chips, as was explained in *3.3.1 Product development*. The frying time was changed from 35 to 45 seconds on each side. The fried chips were placed in a colander to strain off extra oil and then placed on paper towel. In addition, the chips were lightly seasoned, prior to serving.

Figure 3.21: Deep-fried chip (top) and improved deep-fried chip (bottom).

Table 3.23: Formulation of the improved deep-fried chip

Improved chip formulation	
Ingredients:	**%:**
Flour	12.2
White masa flour	13.8
Salt	0.4
Cheese and chives seasoning	1.3
Cheese and chives seasoning for dusting	0.7
Water	19.3
Olive oil	1.5
Sunflower oil, for frying	50.8
Total	100.0

II. Demographic profile of the consumer panel

The consumer testing for the improved deep-fried chip were conducted in May of 2022. Ninety-nine consumers, 67 female and 32 male panellists, aged between 18 and 60 years, were sourced from staff and students, both under- and post-graduate from the Bloemfontein campus of the UFS, Bloemfontein, SA (Table 3.24). The panel included 75.0% of the participants from the first scaling, since all panellists from the first test were not available, rendering it impossible to include them all. The improved chip was presented to the consumer panel as a single sample and was not tasted with other samples. Observations again showed that the female gender constituted the majority of those who participated in the study. The first JAR profile for the chips did not include the age and gender of the respondents, as participants were regular consumers of snack foods. However, the researcher included gender and age data in the second JAR task to reveal how gender and age affect consumer choices and acceptance of newly developed products. Almost three-fourths of respondents were 35 years or younger (77.8%), while only 22.2% were older than 35 years.

Table 3.24: Demographic profile of consumers participating in the overall liking task and JAR profile for the improved deep-fried chip.

Age group	n (out of 99)	%
<35	77	77.8
35 and older	22	22.2

III. Consumers' overall liking task

Table 3.25 summarises the hedonic ranking for the deep-fried chip. The chip had a 7.0 ranking, which indicated that it was 'liked moderately' on the hedonic scale.

Table 3.25: Overall liking of the deep-fried chip ($p \leq 0.05$)

Product type	Deep-fried chip
Overall liking	7.0 ± 1.5

IV. Correlations between attributes

In Table 3.26, no significant correlations (≥ ± 0.200) existed between the attributes of the improved deep-fried chip sample.

Table 3.26: Correlation matrix for the deep-fried chip sample

Variables	Overall liking	Aroma	Appearance	Taste	Mouthfeel
Overall liking		0.026	-0.103	-0.085	0.091
Aroma			0.006	0.187	0.048
Appearance				0.010	-0.141
Taste					-0.048
Mouthfeel					

Values in bold are different from 0 with a significance level (p≤0.05).

V. JAR profiles

Figure 3.22 is the JAR profile for the improved deep-fried chip. The JAR levels (green bars) for all the attributes were ≥20.0%, indicated that this sample was still worth developing further.

The JAR percentages for the improved deep-fried chip, were presented as follows: aroma (62.0%); appearance (51.0%); taste (59.0%) and mouthfeel (61.0%). Aroma had only one non-JAR attribute ≥20.0%, namely: too little oily, corny or starchy aroma (22.0%). Appearance had two non-JAR attributes ≥20.0%, namely: too brown in colour (29.0%); and too dull in colour (20.0%). Taste also had only one non-JAR category in the too much range, with 23.0% of consumers agreeing that the chip tasted too savoury. With regards to mouthfeel, one non-JAR category was ≥20.0%, namely for the chip being too soft (21.0%) (Figure 3.22).

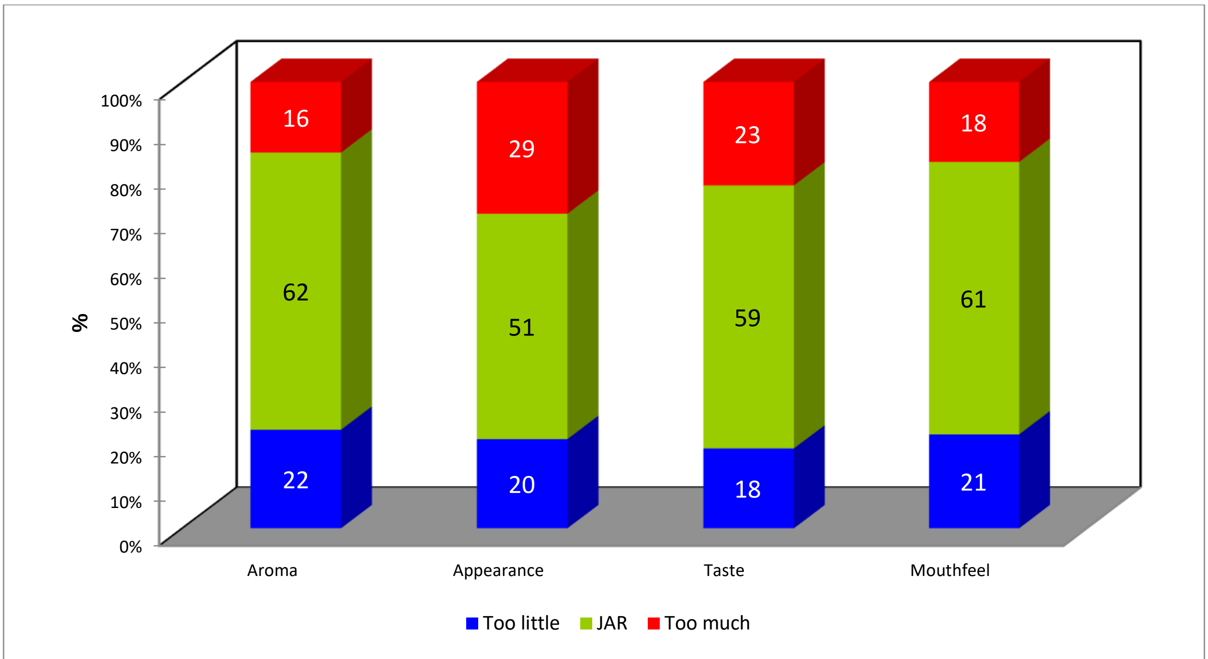

Figure 3.22: JAR profile of the improved deep-fried chip.

VI. Penalty analysis

Table 3.27 is the summary of the penalty analysis for the improved deep-fried chip. The aroma of this sample had an unacceptable net penalty (1.129), along with one non-JAR category being ≥20.0% (‘too little oily, corny or starchy aroma’ = 22.1%). The mean drop for this category was 0.98 on the hedonic scale. The standardised difference had a very strong effect (3.760) and a low p-value (0.000), thereby signifying that this attribute was significant for the overall liking of the sample. The appearance of this sample also had an unacceptable net penalty (1.222), along with both of the non-JAR categories being ≥20.0%. Some of the consumers indicated a too brown appearance (29.5%) while others indicated that it was too dull (20.0%), which resulted in mean drops of 1.30 and 1.11, respectively, on the hedonic scale. The standardised difference had a very strong effect (4.273) and a very low p-value (<0.0001). This indicated that this attribute was significant for the overall liking of the sample. The taste of this sample had a net penalty of 1.704, which rendered it unacceptable. The non-JAR category ‘too savoury’ was ≥20.0%, with 23.1%, resulting in a mean drop of 1.82 on the hedonic scale. The standardised difference was extremely strong (6.452) and had a very low p-value (<0.0001), indicating the significance of taste in the overall liking of the sample. The mouthfeel of the sample had an unacceptable net penalty (1.559), as well as one non-JAR category being ≥20.0% (too soft = 21.0), which resulted in a mean drop of 1.69 on the hedonic scale. The effect of the standardised difference was extremely strong (5.631) and had a very low p-value (<0.0001), showing the significance for mouthfeel on the overall liking of the sample.

Table 3.27: Penalty analysis of the improved deep-fried chip

Variable	Level	%*	Mean (hedonic scale)	Mean drops	p-value	Significant	Penalty	Standardised difference	p-value	Significant
	Too little	22.1	6.43	0.98	0.005	yes	1.129			
Aroma	JAR	62.1	7.41					3.760	0.000	yes
	Too high	15.8	6.07	1.34						
	Too little	20.0	6.47	1.11	0.012	yes				
Appearance	JAR	50.5	7.58				1.222	4.273	<0.0001	yes
	Too high	29.5	6.29	1.30	0.001	yes				
	Too little	17.9	6.12	1.56						
Taste	JAR	59.0	7.68				1.704	6.452	<0.0001	yes
	Too high	23.1	5.86	1.82	<0.0001	yes				
	Too little	21.0	5.90	1.69	<0.0001	yes				
Mouthfeel	JAR	61.1	7.59				1.559	5.631	<0.009	yes
	Too high	17.9	6.18	1.41						

VII. Interpretation of results from the bi-plot chart summary

Figure 3.23 provides the weighted penalties for the improved maize chip. The attributes within in the top right orange box have mean drops of 1 and more as well as non-JAR categories >20.0%, indicating that either the 'too little' or 'too much' categories needed to be changed, in the re-formulation of the sample. The improved chip presented five categories in the orange box, namely: too little corn aroma; too brown appearance; too dull appearance; too savoury taste and too soft mouthfeel. There were no significant correlations between the attributes, however appearance had a very weak negative correlation with overall acceptability and taste had a very weak negative correlation with appearance. Additionally, the 'too savoury' taste and 'too little aroma', should be addressed to improve the sample. Both appearance and taste had mean drops of 1.30 and 1.82, respectively (Table 3.27). The mean drops as well as the position of appearance and taste, indicate that if the intensities of the categories in the formulation are altered, all other non-JAR categories will move closer to being just-about-right.

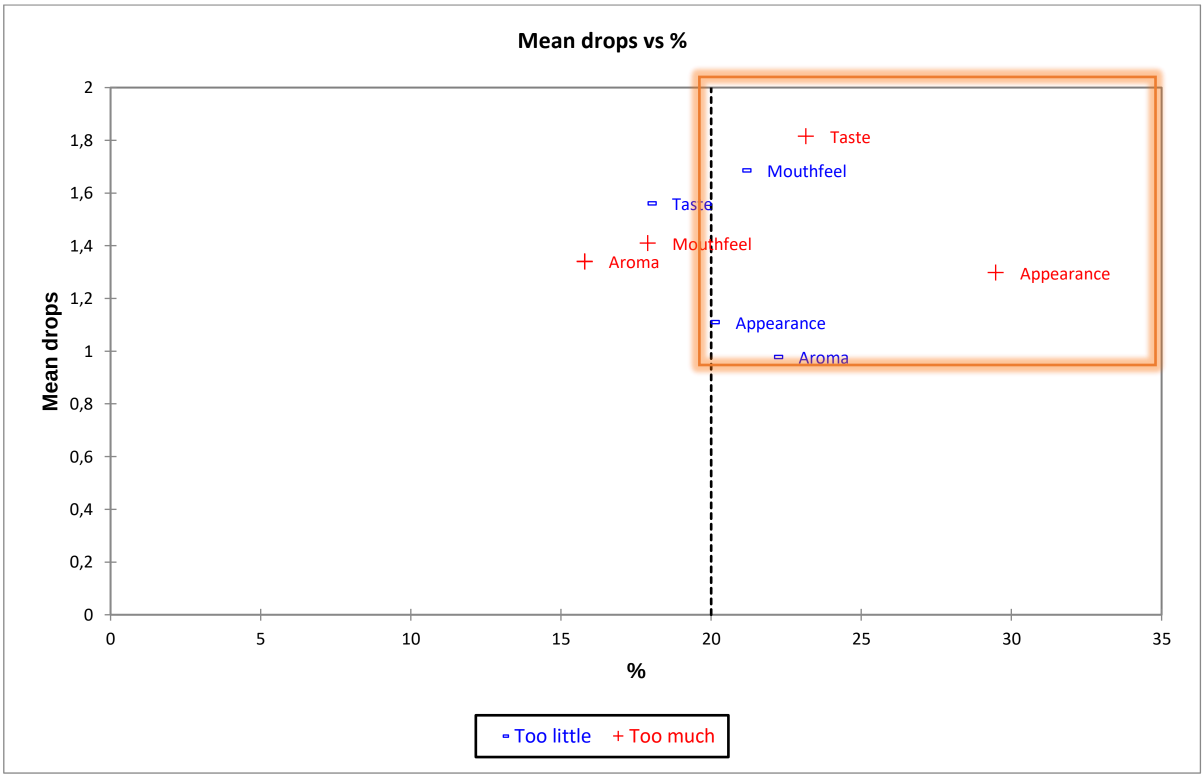

Figure 3.23: Bi-plot for mean drop attributes for the improved deep-fried chip*.

VIII. The multisensory experience of food: the impact of appearance and colour on consumer perception and acceptance

Based on the above findings, food experience is multisensory, with complex interactions between the senses and individual differences in sensory perception (Hoppu, Puputti and Sandell, 2021). Saint-Eve *et al.* (2004) confirmed that low-fat yoghurts were perceived as thicker and stickier when one aroma complex, such as strawberry, was present. Further, Periche *et al.* (2015) found that marshmallows with different sugar levels received better consumer acceptability, when strawberry flavouring was doubled, because panellists preferred a more intense aroma. A study by Du Toit *et al.* (2018) tested consumer liking of three pink marshmallow samples; two being commercial brands and one where gelatin was replaced with cactus pear mucilage. This study reflected no difference in the liking of any of the three samples, reiterating the importance of flavouring to mask unwanted flavours, such as the grassy aroma associated with the mucilage.

As one of the most significant sensory quality attributes of fresh and processed food products, appearance plays an influential role. Colour is the first quality parameter consumers assess when evaluating food and it plays a crucial role in product acceptance. A consumer's first perception of food is its appearance, which is primarily determined by the colour of its surface (Leon *et al.*, 2006). Consumers use appearance factors to indicate freshness and flavour quality, and the colour is considered the most essential attribute to any food’s appearance. Furthermore, colour influences consumer preferences and choices in the food industry. Colour is well-correlated with other sensory quality attributes and consumers generally associate pleasant flavours with attractive colours (Pathare *et al.*, 2013). For example, the attractive display of fresh produce in supermarkets can stimulate consumers to purchase fruit and vegetables. However, an important component of attractive presentation is the colour of the material, which the food is presented on (Schifferstein, Howell, and Pont, 2017). Additionally, Schifferstein, Howell and Pont (2017) investigated consumer acceptability of vegetables, by placing colourful vegetables on different coloured backgrounds; the results showed that the coloured backgrounds influenced the perceived attractiveness of the vegetables. Furthermore, Schifferstein and Howell (2019), studied the attractiveness of tomato, carrot, yellow bell pepper, eggplant and mushroom on five different background colours, varying from neutral grey to black.

The results concluded that consumers found the vegetables more attractive on darker backgrounds.

The colour of food can also communicate different meanings to consumers, as colour is one of the most important quality parameters. For instance, some colours are associated with ripeness (green and red), whereas others could be associated with spoilage (browning); thus, the colour of different foods communicate crucial properties to the consumer (Pathare *et al.*, 2013). According to Spence *et al.* (2015), a growing body of research shows that people associate specific colours with particular tastes. Humans begin to associate certain colours with various foods from birth and equate these colours to particular tastes and flavours, throughout life (Maina, 2018). It is widely believed that white is associated with saltiness, due to the whiteness of sodium chlorite, while pink or red colours can be associated with sweetness, because red foods, such as berries and cherries, tend to be sweeter than yellow, white, brown or orange varieties (Dematté *et al.*, 2006). Moreover, it may be expected that a yellow pudding will have a banana or lemon flavour and red jellybeans, to have a cherry or cinnamon flavour (Endrizzi *et al.*, 2015). Despite the broad cultural differences in colour use across cuisines, these cross-modal correspondences persist across cultures and at least over the last three decades (Zhou *et al.*, 2015).

In the eyes of consumers, the packaging is the most tangible representation of a brand or product (Hart Design, 2016). A subconscious judgement is made about a product within 90 seconds, and 62-90% of consumers make this judgement based solely on the colour of the product. This can be attributed to the fact that colour registers much faster than text or complex graphics. Additionally, nearly 85.0% of consumers say that colour is the most important factor, when choosing a product (WebFX, 2020). In addition, the packaging of a food product can also influence consumers' taste. In a study by Samuel (2013), 15.0% more yellow colour was added to the outside of 7-Up cans, and consumers claimed that the drink tasted more lemony. However, it is worth noting that consumers could not see the colour of the drink itself and the only visual cue was the colour of the can (Spence, 2018).

3.5.2 Conclusion on JAR profile 2

When developing new products or reformulating existing ones, the product's sensory attributes should satisfy the consumer (Ortega-Heras *et al.*, 2019). According to the above results, the taste, aroma and appearance of the improved deep-fried chip needed reformulation. It is, thus, proposed that consumers associate the colour of the chip with a flavour, thereby suggesting that the appearance of the chip should be linked to its flavour (taste and aroma). This could be achieved by dusting the chip with a seasoning and/or colouring with a known flavour. For example, the chip could be dusted with a well-known red tomato seasoning.

3.6 RESULTS AND DISCUSSION ON JAR PROFILE 3

3.6.1 Flavoured chip

I. Product improvement

As concluded in the second JAR profile of the chip, consumers associate the appearance (colour) of the chip with the flavour (texture, taste and aroma) (Pathare *et al.*, 2013). The chips were coated with a seasoning that represented a known flavour and colour. The addition of seasoning to the chip influenced the taste, appearance and aroma attributes. The three samples included in this JAR task were the original maize chip, a fruit chutney flavour (NJ1024P) and a sweet tomato flavour (NJ0264). A light brown colour was imparted by the fruit chutney chip seasoning, while a red colour was imparted by the sweet tomato chip seasoning (Figure 3.24). Table 3.28 shows the formulation of the fruit chutney and sweet tomato chips. The same technique was used to make all three variations of the chips as mentioned in *3.3.1 Product Development.* For this JAR task, the two seasonings were evenly sprinkled over the chips, using a tea sieve upon cooling.

Figure 3.24: Tasting tray from JAR profile 3. Chutney chip sample (left); tomato chip sample (middle); and original chip sample (right).

Table 3.28: Formulation of the flavoured chip samples

Sweet tomato flavour		Fruit chutney flavour	
Ingredients:	**%:**	**Ingredients:**	**%:**
Flour	11.9	Flour	11.9
White masa flour	16.3	White masa flour	16.3
Salt	0.3	Salt	0.3
Water	19.9	Water	19.9
Olive oil	1.5	Olive oil	1.5
Sunflower oil, for frying	49.7	Sunflower oil, for frying	49.7
Fruit chutney seasoning (NJ1024P)*	0.4	Sweet tomato seasoning (NJ0264)*	0.4
Total	100.0	**Total**	100.0

*Nicola-J Flavours & Fragrances, 64 Capital Hill Commercial Estate, Le Roux Avenue, Midrand, 1683.

II. Demographic profile of the consumer panel

The JAR task of the flavoured chips was conducted in August of 2022. Ninety-nine consumers, 83 female and 14 male panellists, aged between 18 and 65 years, were sourced from staff and students, both under- and post-graduate, from the Bloemfontein campus of the UFS (Table 3.29). The panel included 75.0% of the participants from the first and second JAR scaling's of the chips. All the participants from the previous JAR scaling's could not participate, due to their unavailability; this rendered it impossible to include them all. As observed in the first and second JAR scaling's, the female gender represented most of those who participated in the study. Among respondents, the most spoken home language was Afrikaans and IsiZulu; respectively, 53.5% and 12.1%. As with the previous JAR task, almost three-quarters of the respondents were 35 years or younger (71.7%), while only 28.3% were older than 35 years.

Table 3.29: Demographic profile of consumers participating in the overall liking task and JAR profile for the flavoured chips.

Variable	n=	Categories	n=	%
Gender	99	**Female**	83	83.9
		Male	14	14.1
		Other	1	1.0
		Prefer not to answer	1	1.0
Home Language	99	**Afrikaans**	53	53.5
		English	7	7.1
		Ndebele	2	2.0
		Northern Sotho	2	2.0
		Other	1	1.0
		Southern Sotho	5	5.1
		Tsonga	1	1.0
		Tswana	6	6.1
		Venda	2	2.0
		Xhosa	8	8.1
		Zulu	12	12.1
Age group	**99**	**<35**	71	71.7
		35 and older	28	28.3

III. Consumers' overall liking task

Table 3.30 shows that both the chutney chip (7.35) and sweet tomato chip (7.23) had the highest rankings on the hedonic scale (like moderately) and did not differ between each other. The original chip had the lowest ranking, of 5.67 (neither like not dislike), and differed significantly (p = 0.05) from the overall liking of the chutney and sweet tomato samples.

Table 3.30: Overall liking for the three flavoured chip samples

	Original	Chutney	Sweet tomato
Overall liking	$5.67^{a} \pm 1.73$	$7.35^{b} \pm 1.37$	$7.23^{b} \pm 1.37$

Means with different superscripts in the same row differ significantly (p≤0.05).

IV. Correlations between attributes

For the original chip sample, five positive correlations were observed. The overall liking had three positive correlations: a weak correlation with appearance (0.344), a weak correlation with aroma (0.284), and a strong correlation with taste (0.640). These correlations showed that if these attributes could be improved, the overall liking of the original chip sample would increase. The appearance had a weak positive correlation with aroma (0.282). Thus, increasing the aroma would increase the appearance JAR percentage. Furthermore, the aroma had a weak positive correlation with taste (0.259). This correlation also indicated that improving the taste, would positively impact the aroma JAR percentage (Table 3.31).

Table 3.31: Correlation matrix for the three flavoured chip samples

Variables	Overall liking	Appearance	Aroma	Taste	Mouthfeel
Overall liking		0.344 0.470 -0.231	0.284	0.640 0.320	0.236 0.356
Appearance			0.282 0.254		
Aroma				0.259	
Taste					
Mouthfeel					

Values in bold are different from 0 with a significance level (p≤0.05).

Original chip; Chutney chip; Tomato chip

The overall liking of the chutney-flavoured chip showed two positive correlations (Table 3.31); one moderate correlation with appearance (0.470) and one weak correlation with mouthfeel (0.236). Both correlations suggested that the overall liking would increase if the appearance and mouthfeel could be improved.

The tomato-flavoured chip sample showed three positive correlations and one negative correlation (Table 3.31). The overall liking had one weak negative correlation with appearance (-0.231) and two weak positive correlations with taste (0.320) and mouthfeel (0.356). This suggested that if the appearance was less red in colour, the overall liking would increase. In contrast, if the taste and mouthfeel increased, the overall liking would increase. The appearance had a weak positive correlation with aroma (0.254), suggesting that increasing the aroma would increase the appearance JAR percentage.

V. JAR profiles

Figure 3.25 to 3.27 shows the JAR profiles of all the chip samples.

a) <u>Original chip sample:</u>

The JAR levels (green bars) were ≥20.0% for two of the samples, indicating that these two samples were worth developing further. The original chip had a JAR percentage of only 18.0%, rendering it not suitable for further development (Figure 3.25).

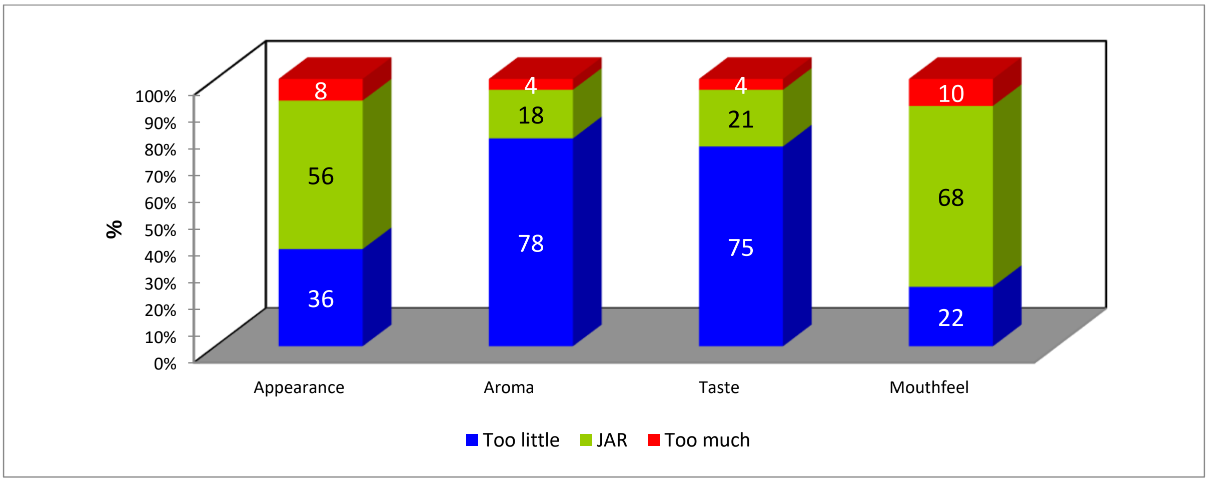

Figure 3.25: JAR profile of the original chip.

b) Chutney-flavoured chip sample

The JAR percentages for the chutney-flavoured chip sample were as follows: aroma (71.0%); appearance (73.0%); taste (79.0%); and mouthfeel (75.0%). The appearance was the only attribute with a non-JAR category ≥20.0%, namely too dull in appearance (26.0%). All the other non-JAR categories, for all the attributes, were <20.0%, indicating that no changes were needed for those categories (Figure 3.26). According to Meullenet, Xiong and Findlay (2008), a JAR rating of 70% and above for all attributes, could conclude a product to be optimum enough (JAR), to be regarded as accepted by consumers. All the attributes for the chutney chip sample reached a JAR percentage of >70.0%: thus, this sample was regarded as reaching consumer acceptance with no need for further improvement.

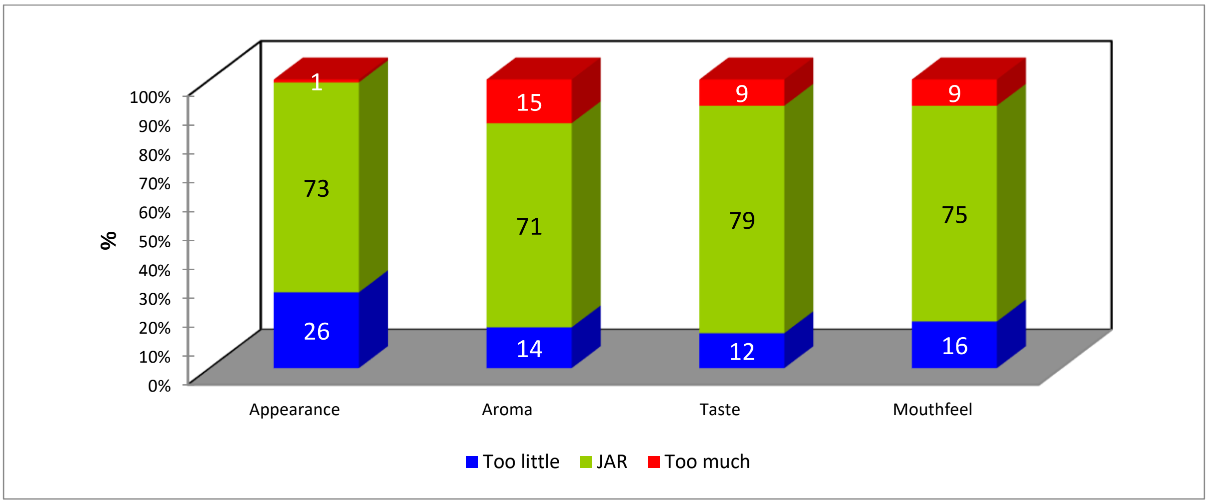

Figure 3.26: JAR profiles of the chutney-flavoured chip.

c) Tomato-flavoured chip sample:

The JAR percentages for the tomato-flavoured chip were as follows: aroma (74.0%); appearance (72.0%); taste (69.0%); and mouthfeel (65.0%). All the attributes for the tomato chip had two non-JAR categories being ≥20.0%: aroma and appearance were found to be too high (27.0%) and too colourful/bright (21.0%), respectively. For the too little categories, the taste was too bland (26.0%), while the mouthfeel was too soft (29.0%). All the other non-JAR categories, for all the attributes, were <20.0%, indicating that no changes were needed for those categories (Figure 3.27).

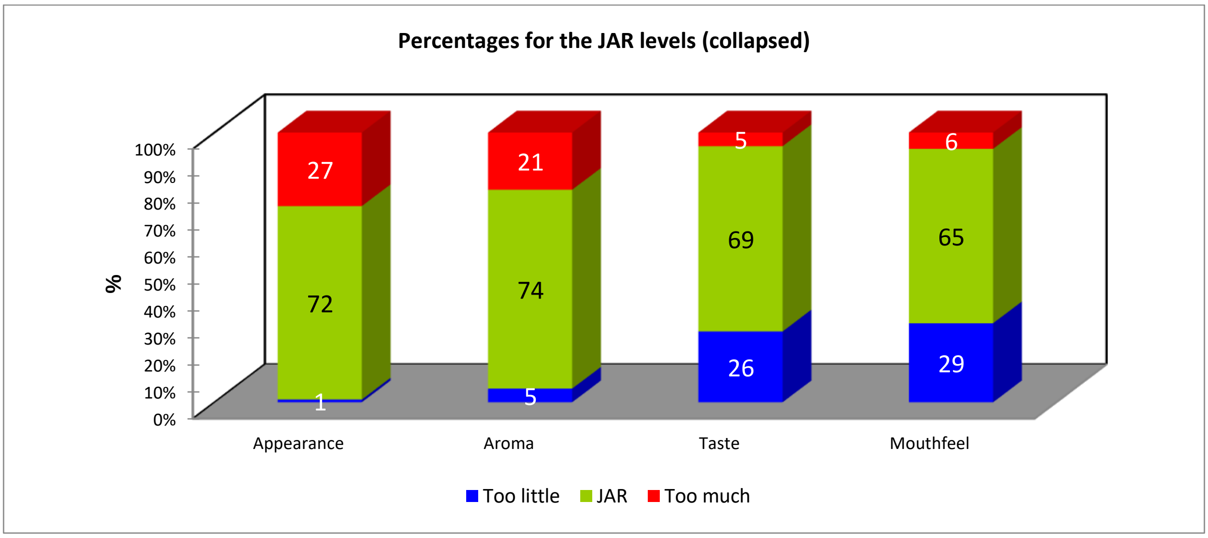

Figure 3.27: JAR profiles of the tomato-flavoured chip.

VI. Penalty analysis

a) <u>Original chip sample:</u>

Table 3.32 is the summary of the penalty analysis for the original chip sample, but having a JAR percentage of only 18.2% for aroma, rendered it unsuitable for further development. Therefore, the penalty analysis for this sample will not be discussed.

Table 3.32: Penalty analysis of the original chip sample.

Variable	Level	%*	Mean (hedonic scale)	Mean drops	p-value	Significant	Penalty	Standardised difference	p-value	Significant
	Too little	36.4	4.81	1.37	0.000	Yes	1.159			
Appearance	JAR	55.6	6.18					3.506	0.001	yes
	Too high	8.0	6.00	0.18						
	Too little	77.8	5.40	1.49	0.001	Yes				
Aroma	JAR	18.2	6.89				1.494	3.507	0.001	yes
	Too high	4.0	5.25	1.64						
	Too little	74.8	5.16	2.13	<0.0001	Yes				
Taste	JAR	21.2	7.29				2.055	5.524	<0.0001	yes
	Too high	4.0	6.50	0.79						
	Too little	22.2	4.77	1.17	0.005	Yes				
Mouthfeel	JAR	67.7	5.94				0.847	2.333	0.022	yes
	Too high	10.1	5.80	0.14						

b) <u>Chutney-flavoured chip sample:</u>

Table 3.33 is the summary of the penalty analysis of the chutney-flavoured chip sample. The appearance of the sample had a high net penalty (1.606) and one non-JAR category being ≥20.0%. The respondents found the appearance to be too dull (26.3%), resulting in a mean drop of 1.60. The standardised difference had an extremely strong effect (6.104) and had a very low p-value (<0.0001), indicating that the appearance of the sample was significant on the overall acceptability. The aroma of the sample had a high net penalty (1.085), with the non-JAR category being ≥20.0%. The standardised difference had a very strong effect (3.845) and had a low p-value (0.000), indicating that the aroma was significant in the overall liking of the sample. The taste of the sample had a high net penalty (1.476), but none of the non-JAR categories were ≥20.0%. The standardised difference had a very strong effect (4.885) and a very low p-value (<0.0001), indicating that the aroma had a significant effect on the overall liking of the sample. The mouthfeel of the sample had a high net penalty (1.169), but no non-JAR categories ≥20.0%. The standardised difference had a very strong effect and a low p-value (0.000), indicating that the taste of the sample was significant on the overall acceptability.

Table 3.33: Penalty analysis of the chutney-flavoured chip sample

Variable	Level	%*	Mean (hedonic scale)	Mean drops	p-value	Significant	Penalty	Standardised difference	p-value	Significant
	Too little	26.3	6.19	1.60	<0.0001	yes	1.606			
Appearance	JAR	72.7	7.79					6.104	<0.0001	yes
	Too high	1.01	6.00	1.79						
	Too little	14.1	6.57	1.10						
Aroma	JAR	70.7	7.67				1.085	3.845	0.000	yes
	Too high	15.2	6.60	1.07						
	Too little	12.1	6.17	1.50						
Taste	JAR	78.8	7.67				1.476	4.885	<0.0001	yes
	Too high	9.1	6.22	1.45						
	Too little	16.2	6.19	1.46						
Mouthfeel	JAR	74.7	7.65				1.169	3.970	0.000	yes
	Too high	9.1	7.00	0.65						

c) Tomato-flavoured chip sample:

Table 3.34 is the summary of the penalty analysis of the tomato-flavoured chip sample. The appearance of the sample had a high net penalty (0.822) and one non-JAR category was ≥20.0%. The respondents found the appearance to be too colourful/bright (27.3%), which resulted in a mean drop lower than 1.0 (0.80). The standardised difference had a strong effect and a low p-value (0.007), which indicated that the appearance of the sample was significant on the overall acceptability. The aroma of the sample had an acceptable net penalty (0.576) and only one non-JAR category being ≥20.0%, namely the aroma being too oily, corny or starchy (21.2%); however, it resulted in a mean drop lower than 1.0 (0.62). The standardised difference had a moderate effect (1.856) and had a p-value of 0.065, which indicated that the aroma of the sample had no significance in the overall liking of the tomato chip sample. The taste of the sample had a high net penalty (1.606) and one non-JAR category being ≥20.0%. The respondents found the taste to be too bland (26.3%), which resulted in a mean drop of 1.59. The standardised difference had an extremely strong effect (6.434) and had a very low p-value (<0.0001), indicating that the taste of the sample was significant in the overall acceptability. The mouthfeel of the sample had a high net penalty (1.597) and one non-JAR category being ≥20.0%. The respondents found the sample to be too soft (29.3%), resulting in a mean drop of 1.59. The standardised difference had an extremely strong (6.666) effect and had a very low p-value (<0.0001), indicating that the mouthfeel was significant in the overall liking of the sample.

Table 3.34: Penalty analysis of the tomato-flavoured chip sample.

Variable	Level	%*	Mean (hedonic scale)	Mean drops	p-value	Significant	Penalty	Standardised difference	p-value	Significant
	Too little	1.0	6.00	1.47			0.822			
Appearance	JAR	71.7	7.47					2.281	0.007	yes
	Too high	27.3	6.67	0.80	0.009	yes				
	Too little	5.1	7.00	0.38						
Aroma	JAR	73.7	7.38				0.576	1.856	0.065	no
	Too high	21.2	6.76	0.62	0.066	no				
	Too little	26.3	6.15	1.59	<0.0001	yes				
Taste	JAR	68.7	7.74				1.606	6.434	<0.0001	yes
	Too high	5.0	6.00	1.74						
	Too little	29.3	6.21	1.59	<0.0001	yes				
Mouthfeel	JAR	64.7	7.80				1.597	6.666	<0.0001	yes
	Too high	6.0	6.17	1.63						

VII. Interpretation of the results from the bi-plot chart summary

Figure 3.28 shows the weighted penalties for appearance, aroma, taste and mouthfeel for the chip samples. The attributes within in the top right orange box have mean drops of 1 and more as well as non-JAR categories >20.0%, indicating that either the ‘too little’ or ‘too much’ categories needed to be changed, in the re-formulation of the sample. For the original chip sample, three categories were situated in the orange box, namely: too little corn aroma; too bland taste and too soft mouthfeel. The taste category had the highest mean drop of 2.13 (Table 3.32) and a strong positive correlation with overall liking. Therefore, increasing the intensity of the taste attribute in the formulation of the original chip, would bring all the other non-JAR categories closer to being JAR. The chutney-flavoured chip sample had one category situated in the orange box, namely: too dull appearance. Appearance had a moderate positive correlation with overall liking and a mean drop of 1.60 (Table 3.33), indicating that this attribute could move closer to JAR if the appearance (colour) is addressed in the formulation by adding colouring to the seasoning, rather than adding a more intense seasoning, as seasoning could affect the JAR levels of the aroma and taste attributes. The tomato-flavoured chip sample had two categories situated in the orange box, namely: too bland taste and too soft mouthfeel. Mouthfeel was considered not crunchy enough, although this was a ‘constant’ attribute, since all samples were prepared in the same way. A different flavour blend may resolve the issue, as it can be blended to give additional crunchiness to the chip. Furthermore, there was a weak positive correlation with taste and mouthfeel between overall liking with both categories having a mean drop of 1.59 (Table 3.34). Thus, suggesting that if the intensity of these categories can be improved, it would bring all the non-JAR categories closer to being JAR.

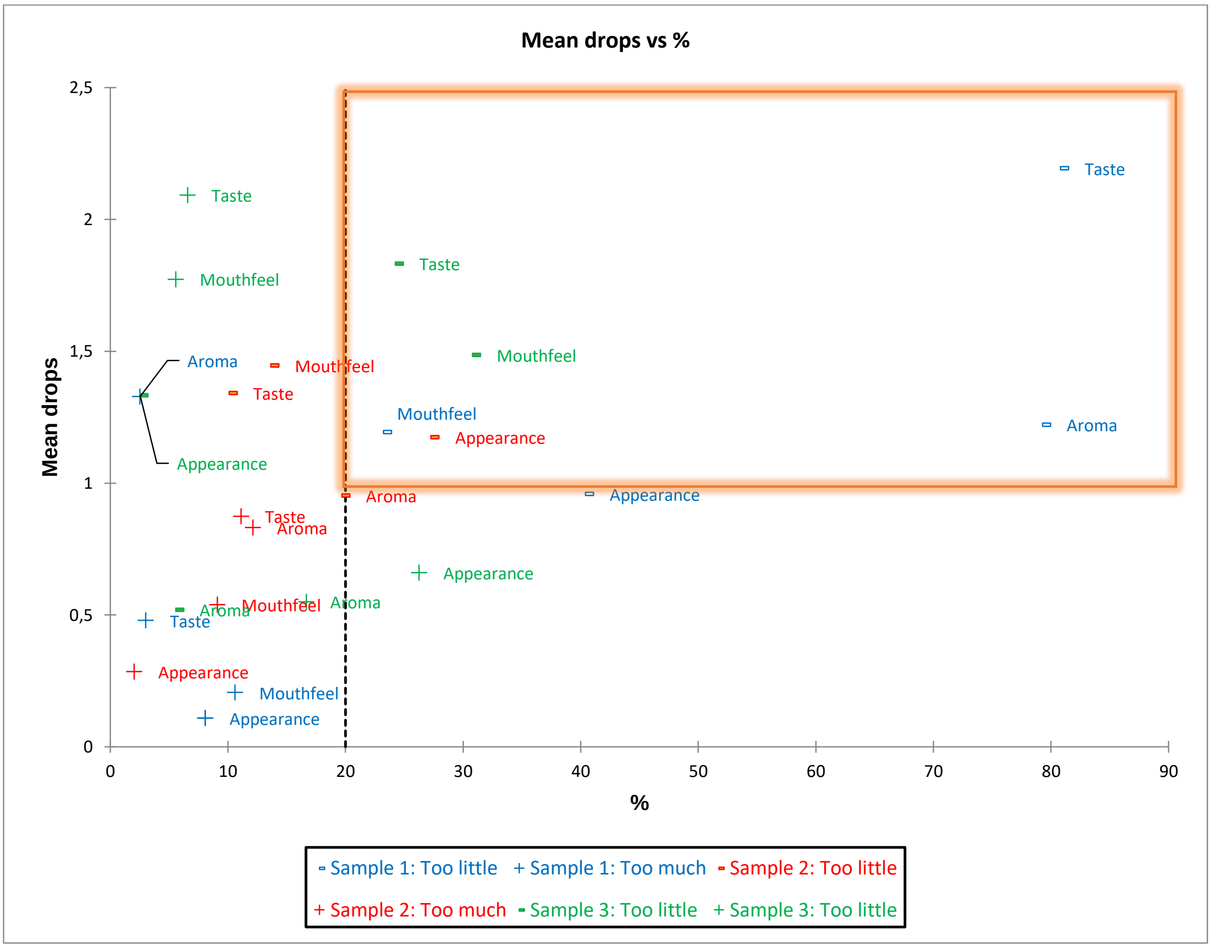

Figure 3.28: Bi-plot for mean drop attributes for the original and flavoured chip samples. ***Original; chutney; tomato.***

3.6.2 Conclusion on JAR profile 3

The findings proved that appearance played a major role in the overall liking of food, for consumers (Leon *et al.*, 2006). As mentioned by Pathare *et al.* (2013), consumers often relate colour (appearance) to flavour (texture, taste and aroma) and vice versa. Thus, according to the findings, the aim was to address the appearance attribute, by evenly coating the chips with a seasoning, which not only coloured the chip, but also flavoured it; thus, appeasing the appearance, taste and aroma attributes. The duration of frying was kept the same as the original chip technique (JAR profile 1). A general summary for each sample is provided below:

I. Original chip:

All the attributes for the original chip had unacceptable JAR percentages, especially the 18.0% for aroma. This rendered the sample unworthy of further development.

II. Chutney-flavoured chip:

The chutney-flavoured chip's JAR percentages, for all its attributes, were all >70.0%, namely appearance (73.0%); aroma (71.0%); taste (79.0%); and mouthfeel (75.0%). This sample only had one non-JAR category being ≥20.0%, which was appearance (26.0%). As mentioned in the JAR profile discussion of the chutney chip sample, attributes which received >70.0% in the JAR range, are considered acceptable and require no further reformulation (Meullenet, Xiong and Findlay, 2008). Thus, this sample was considered JAR.

III. Tomato-flavoured chip

The tomato-flavoured chip had only two attributes >70.0%, namely appearance (72.0%) and aroma (74.0%). However, four attributes also had percentages in each non-JAR category that were ≥20.0%. The appearance was too brown (27.0%) and the aroma was much too oily, corny or starchy (21.0%). Furthermore, the taste was much too bland (26.0%), with the mouthfeel being much too soft (29.0%).

In conclusion, the chutney-flavoured sample was the only sample to reach JAR, as all the attributes were >70.0%. However, the appearance attribute had one non-JAR category ≥20.0%, indicating the significance of the appearance being 'too dull' to the respondents. This implied that the appearance could be improved, by adding colouring to the coating seasoning, after frying.

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CHAPTER 4: CONSUMERS' ATTITUDES AND KNOWLEDGE OF MAIZE AS A FOOD SOURCE

4.1 INTRODUCTION

Globally, maize contributes significantly to human and animal diets and thus plays a pivotal role in food security (Wu and Guclu, 2013). Furthermore, it was reported by Drammeh, Hamid and Rohana (2019) that household food insecurity is the leading cause of malnutrition and is directly or indirectly caused by inadequate food consumption and poor diet quality. Lower-income groups are especially susceptible to malnutrition-related diseases and deaths due to the inaccessibility of affordable nutrient-dense foods (Unicef, 2020). Drammeh, Hamid and Rohana (2019) further indicate that inadequate nutrition can impair physical and mental development as well as reduce productivity among children under the age of five and throughout their lives.

South Africa is well-known for its good quality maize which serves as a staple crop that is produced throughout the country under diverse climatic environments (Zuma, Kolanisi, and Modi, 2018; Du Plessis, 2003). Moreover, maize is crucial to commercial and subsistence farming communities as the majority of South Africans (67% to 83%) consume maize-based products, with an average daily consumption of 476 g to 690 g per person (GrainSA, 2017). Notably, South Africa is the continent's top maize producer, with the North West province, Free State and the Mpumalanga Highveld being the most prominent production areas. Maize is also a major animal feed with a consumption growth from 3.3 million tons to 4.8 million tons between 2000 and 2014. At the same time, human consumption of maize increased from 4 million tons to 4.5 million tons during the same period (Scheltema *et al*., 2015). As an essential raw material, maize is instrumental in the production of starch, oil, protein, alcoholic beverages, sugar, and fuel (Wu and Guclu, 2013). Most South Africans prefer white maize for human consumption, whereas yellow maize is allocated exclusively to livestock (Khumalo, Schönfeldt and Vermeulen, 2011). However, according to Nuss and Tanumihardjo (2010), maize provides an unbalanced supply of essential nutrients necessary for human nutrition, such as the essential amino acids lysine and tryptophan. Furthermore, the water-soluble vitamin niacin (vitamin B_3) is biologically unavailable to humans. Consequently, long-term consumption of diets consisting mainly of maize cause a deficiency in this vitamin that can result in pellagra. Pellagra is a disorder resulting from the inadequate dietary intake of niacin and/or tryptophan, manifested by the characteristic symptom dermatitis on areas of the skin that are exposed to the sun (Kies, Kan and Fox, 1984). However, the nixtamalization process offsets this disorder due to it being beneficial to humans nutritionally by increasing the availability of niacin, tryptophan, and lysine, as well as the calcium content. Consequently, leading to the prevention of pellagra, rickets, and osteoporosis in some American societies (Ranum, Peña-Rosas and Garcia-Casal, 2014; Bressani, 1990).

Nixtamalization, discovered by the native Latin Americans, involves the cooking and soaking of maize kernels in an alkaline solution, followed by rinsing and grinding to produce *masa*. Masa is dried into maize meal as well as more refined into flour (Ranum, Peña-Rosas and Garcia-Casal, 2014). According to Serna-Saldivar (2015), wood ashes were historically the first calcium source used to nixtamalize maize kernels. However, it has been replaced by lime (calcium hydroxide), which is widely used by households and the maize processing industry today (Santiago-Ramos *et al*., 2018a). Because of the process, nixtamalized maize products are characterised by enhanced physicochemical, nutritional, textural, and sensorial properties (Pappa, de Palomo and Bressani, 2010). Santiago-Ramos *et al*. (2018b) highlight that nixtamalization softens the pericarp and endosperm to facilitate grinding. Furthermore, the process is known to reduce mycotoxins by up to 90% as it causes several physicochemical changes in maize kernels (Schaarschmidt and Fauhl-Hassek, 2019). Mycotoxins are toxic secondary metabolites of fungi that commonly contaminate maize in the field and/or during storage (Smith, Stoltzfus and Prendergast, 2012). As a result, these toxic metabolites can pose serious health risks to both humans and animals if mycotoxin-contaminated maize is consumed (Mboya and Bogale, 2012).

The introduction of nixtamalization as a novel maize processing technique would improve the nutritional content and safety of this staple food, therefore positively influencing consumers' food and nutrition security. Furthermore, considering that maize is a staple crop grown by subsistence and commercial farmers alike, the researcher suggests that nixtamalization could be easily and inexpensively implemented by South African households, especially those in close proximity to subsistence crops.

The aim of this chapter was to use a questionnaire to determine the attitudes of respondents at the University of the Free State, Bloemfontein campus toward nixtamalized products and nixtamalization as a novel food processing technique as well as their attitudes toward new food products. Additionally, the questionnaire sought to determine their knowledge and attitudes towards growing and processing their own crops.

4.2 RESEARCH APPROACH AND DESIGN

The research approach that was used in this study was quantitative. Quantitative research encompasses a range of methods concerned with the systematic investigation of social phenomena, using statistical or numerical data. Therefore, quantitative analysis involves measurement and assumes that the phenomena in the study can be measured. It sets out to analyse data for trends and relationships, and to verify the measurements made (Watson, 2015). In this study, respondent's attitudes towards maize as a food source was determined through a questionnaire and the numerical results were analysed, to draw a conclusion on their attitudes and knowledge.

This chapter has two approaches: exploration and description. According to Babbie (2020), an exploratory design aims to provide a better understanding by satisfying the researcher's curiosity, whereas a descriptive design allows the researcher to observe and then describe what was observed. Therefore, the researcher developed a questionnaire, focusing on attitudes and knowledge of maize as a food source. Among the questions were the knowledge of cultivating and agro-processing maize at home, acceptance of nixtamalized maize products, knowledge of maize varieties (colour), including safety, and attitudes to newly developed food products. The questionnaire is, thus, used as an explorative device, to give the researcher a general summary of the respondent's attitudes to maize and maize-based products. The researcher uses the data from the questionnaire to describe consumers' acceptance, knowledge, awareness and attitudes to maize and maize products.

4.3 SAMPLING

The population of the study were students and staff from the University of the Free State on the Bloemfontein campus. Participation in the study was voluntarily and anonymously completed by a sampling size of 186 sensory respondents in the

Sensory Laboratory, at the UFS Agricultural building, during the sensory tasting of the maize chip and maize patty products. This method of sampling, used during the sensory tasting, is called convenience sampling. According to Etikan, Musa and Alkassim (2016), convenience sampling refers to a type of nonprobability sampling, where those who meet certain practical criteria, such as proximity to the study site, availability at a particular time, or willingness to participate, are included. Results obtained through convenience sampling are likely to be biased and should not be considered representative of the population (Etikan, Musa and Alkassim, 2016).

4.4 MATERIAL AND METHODS

Data was collected through a questionnaire and the results were presented in the form of tables and discussions. The researcher's method of analysis intended to identify the significant relationships between variables in the questionnaire, and to provide answers to the research questions, with the assistance of statistical technology. The discussion of the results of the questionnaire begins with the demographic profile of the respondents and then proceeds to discuss their acceptability of the products tasted, their knowledge of the safety of maize, their awareness of maize as a food source, as well as their attitudes to new food items available in stores.

4.4.1 Research instrument

An online electronic questionnaire was used as a means of collecting data for this chapter (Appendix C). Table 4.1 summarises the five sections of the questionnaire, as well as the theme of the questions of each section.

Table 4.1: Summary of the questionnaire the respondents completed

Section:		Type of question:	Theme of questions:
1)	**Demographics** **Questions 1.1 to 1.5**	Majority of the questions were nominal except level of education, which was ordinal.	• Gender • Age • Language • Level of education • Province
2)	**Acceptability of the maize chip and maize patty** **Questions 2.1 to 2.9**	Ordinal questions	• Appearance • Aroma • Taste • Texture • Repetitive consumption • Future purchasing • Home preparation • Willingness to consume in a restaurant

			• Recommendation for friends and family.
3)	**Knowledge and awareness of the safety of maize** **Questions 3.1 to 3.6**	Ordinal questions	• The theme under this section explored the respondent's willingness and/or reluctance to consume maize of different colours. • It further explored the respondent's eagerness to gain more knowledge on the safety of maize, regarding to storage procedures.
4)	**Consumers' awareness of maize as a food source** **Questions 4.1 to 4.11**	Ordinal questions	• The theme under this section explored the respondent's exposure to maize of different colours, regarding consumption, preparation, cultivation and knowledge of their existence. • It also explored what would convince the respondents to purchase and consume maize of different colours, such as its availability, accessibility, price and price comparison to similar foods.
5)	**Knowledge and awareness of new food products and trends** **Questions 5.1 to 5.14**	Ordinal questions	• The theme under this section explored the respondent's willingness and/or reluctance to purchase and consume newly developed food products, based on their trendiness in the market and/or their popularity, and acceptance by peers.

Although 186 respondents completed the questionnaire, the number of responses (n) for each question is outlined in the tables, along with the missing values.

4.4.2 Data collection procedure

Respondents completed an online electronic EvaSys© questionnaire during the sensory tasting of two developed nixtamalized maize products: a maize chip and a maize patty. The questionnaire is attached as Appendix C. The tastings took place on two consecutive days: the 20th and 21st of October 2021 from 09:00 to 13:00 in the Sensory Laboratory at the University of the Free state (UFS), Agricultural building on the Bloemfontein campus. Each respondent was allocated 15 minutes to taste the products first before completing the questionnaire, which took approximately five minutes. Data was collected, whereby respondents' answers were captured and analysed, to provide a generalised overview of the study population. Each of the respondents received a sachet of instant coffee as a reward, as shown in Chapter 3, Figure 3.6.

4.4.3 Data analysis

The data from the questionnaire was captured on the EvaSys© software, and from there it was imported into XLSTAT sensory analysis package for Excel (Addinsoft, 2022). The frequencies for each question and their possible answers were calculated. Furthermore, the data was analysed descriptively with the use of the SPSS (Statistical Package for the Social Sciences) version 28 package. Reliability analysis was done by calculating the Cronbach's Alpha for the questionnaire. The Cronbach's Alpha gives a measurement for internal consistency.

Spearman's correlation was used to determine whether there were significant relationships between the different questions/variables in the questionnaire (Wu, Xia and Yu, 2016). Spearman's correlation coefficient is a statistical measure of the strength of a monotonic relationship between paired data. The closer the correlation is to 1.00, the stronger the monotonic relationship (Wu, Xia and Yu, 2016). For the purpose of this study, the researcher only focused on correlation coefficients from 0.50 to 1.00, denoting a moderate to very strong relationship between the two variables (Table 4.2).

Table 4.2: Grading of Spearman's correlation coefficient (Statstutor, 2019).

Grading Standards	Correlation Degree
p = 0	No correlation
$0 < r \leq 0.19$	Very weak
$0.2 \leq r \leq 0.39$	Weak
$0.4 \leq r \leq 0.59$	Moderate
$0.6 \leq r \leq 0.79$	Strong
$0.8 \leq r \leq 1.0$	Very strong
1.00	Monotonic correlation

4.4.4 Reliability and validity

According to Table 4.3, all internal consistency estimates, as determined by Cronbach's alpha coefficient, exceeded 0.80.

Table 4.3: Cronbach's alpha values

	Cronbach's Alpha	Standardized Cronbach's Alpha
Cronbach's alpha for the Likert questions	0.895	0.901

Cronbach's alpha for the entire question set	0.860	0.884

A reliable Cronbach Alpha coefficient confirms that the individual items of a construct, measured the same construct or concept consistently. The Cronbach Alpha coefficient for each item in the questionnaire was above 0.8, rendering the data reliable.

4.4.5 Ethical considerations

This study involved using people as research respondents; therefore, it was of great importance that the researcher presented the research study information leaflet and consent form in the study (Appendix D). The information leaflet indicated that the researcher gained ethical clearance for the study to take place. The objectives of the ethical clearance were to ensure that no one was harmed during the study. The information leaflet and consent form covered information that was not emotionally and physically harmful to the respondents. As part of the process, respondents had to complete an allergy checklist, to ensure that their health and safety were not compromised. Questionnaires were completed anonymously and voluntarily to ensure respondents responded freely to each question.

Ethical clearance (UFS-HSD2021/0668) was obtained from the General/Human Research Ethics Committee (GHREC) at the UFS on 2 August 2021, prior to the questionnaire being completed by the respondents (Appendix A). Thereafter, the amended ethical application was approved on 28 March 2022 (UFS-HSD2021/0668/22).

4.5 RESULTS AND DISCUSSION

This section presents a detailed discussion of the questionnaire's results as well as significant relationships between questions and related variables identified as Spearman correlation coefficients. As mentioned previously, the researcher discussed only correlation coefficients from 0.50 to 1.00, which indicated a moderate to very strong relationship between two variables, in the questionnaire (Statstutor, 2019).

4.5.1 Demographics

The demographic profile of respondents allows researchers to gain background information on the respondents, thus, providing a broad understanding of the different characteristics of a population (Dobosh, 2017). This information is particularly useful in explorative studies, as it provides a general picture of the preferences of each population group, within a sample (Fairlie, 2022). This section provided a brief profile of the respondents. The questions covered five bases, namely: gender: age; language; level of education; and province. The demographic results are summarised in Table 4.4.

Table 4.4: Demographics of the respondents.

I. Gender:

Categories	n=177	%
Male	32	18.1
Female	145	81.9

II. Age Group:

Categories	n=178	%
18-24 years	95	53.4
25-35 years	45	25.3
36-59 years	35	19.7
60 and older	3	1.6

III. Home language:

Categories	n=180	%
Sesotho	29	16.0
IsiXhosa	16	8.9
IsiZulu	14	7.8
Setswana	7	3.9
Afrikaans	84	46.7
English	25	13.9
Other:		
TsiVenda	2	1.0
SiSwati	1	0.6
Tsong	1	0.6
Nadebele	1	0.6

IV. Highest level of education/schooling:

Categories	n=183	%
Attended secondary school (grade 8-11), but never completed Matric.	5	2.7
Completed Matric	11	6.0
Currently studying to obtain a tertiary qualification.	55	30.1
Attended tertiary education but did not complete the course.	8	4.4
Obtained a tertiary qualification (for example: a certificate, diploma or bachelor's degree).	20	10.9

Postgraduate degree (Honours/Masters/PhD).	84	45.9

V. Home Province:

Categories	**n=183**	**%**
Western Cape	6	3.3
Northern Cape	10	5.5
North West	2	1.1
KwaZulu-Natal	15	8.2
Limpopo	3	1.6
Free State	98	53.6
Mpumalanga	5	2.7
Gauteng	18	9.8
Eastern Cape	19	10.4
I did not grow up in South Africa.	7	3.8

According to Table 4.4, concerning gender, female respondents were the majority compared to male respondents, as research by Laureati *et al*. (2016) has presented that the female gender is mostly responsible for the food choices and consumption decisions in the majority of households. The 18 to 24-year group was more than half (53.4%), followed by the 25 to 35 age group (25.3%). Age 36 to 59 (19.7%) and 60 years and older (1.6%) were the least participating age groups. In the study, students and staff from the UFS were used, consequently making them the largest age group that completed the questionnaire.

Regarding language, nearly half of all respondents (46.7%) were Afrikaans speakers. It was followed by Sesotho (16.0%), English (13.9%), isiXhosa (8.9%), isiZulu (7.8%) and Setswana (3.9%). Tsivenda (1.0%) was the second least spoken language, whereas SiSwati, Tsonga and Ndebele were the least spoken languages of the respondents, all resulting in 0.6%. Historically, the language of instruction at the UFS was Afrikaans for 45 years (1948 to 1993); this could be a major attribute to most of the respondents speaking Afrikaans as a home language (UFS history, n.d.).

Almost half (45.9%) of respondents had a postgraduate qualification, such as an honors degree, masters degree or PhD. The results reveal that: 30.1% were studying towards an undergraduate degree, diploma or certificate; 10.9% of the respondents had a tertiary qualification; 4.4% attended tertiary education but did not complete their enrolled course; 6% of the respondents completed secondary school education; whereas 2.7% attended secondary school but did not matriculate. As previously mentioned, the researcher used students and staff from the UFS Bloemfontein campus as respondents, therefore validating that almost all the respondents had received formal education.

Respondents that took part in the questionnaire were from different provinces in South Africa, while some were born in other countries. More than half (53.6%) of the respondents were originally from the Free State, while the remaining respondents were from other parts of the country, including non-South African citizens. It was, in descending order, as follows: the Eastern Cape (10.4%), Gauteng (9.8%), KwaZulu-Natal (8.2%), Northern Cape (5.5%), Western Cape (3.3%), Mpumalanga (2.7%), Limpopo (1.6%) and North West (1.1%). Only 3.8% of the respondents were not born and raised in South Africa. As mentioned previously, data was collected in Bloemfontein, the capital city of the Free State Province, and as a result, most of the respondents were originally from the Free State.

4.5.2 Acceptability of the products tasted during sensory analysis

Statements in this section provide insight into the respondents' likes and dislikes for the sensory attributes of the newly developed maize chip and maize patty products (Questions 2.1 to 2.9). Furthermore, results are provided on the respondents' willingness to consume, purchase, prepare, and order these products in a restaurant or recommend the products to family and friends.

I. Appearance

The sensory aspects of new food products are important for consumer acceptance (Mishyna, Chen and Benjamin, 2020). The results (Table 4.5) for those that liked the appearance of the products were 58.3% (category 4+5), while only a few (4.9%) (category 1+2) of respondents did not like the appearance. Furthermore, some (36.8%) respondents remained neutral, claiming to neither like nor dislike the appearance of the products. The overall mode was category 4, indicating that most of the liked the appearance of the products.

Table 4.5: Respondents liking of the appearance of the products that were tasted.

Question	Nr. of missing values	Category	n=182	%
I liked the appearance of the product.	4	1.	1	0.5
		2	8	4.4

		3	67	36.8
		4	68	37.4
		5	38	20.9

Category: 1= do not like at all; 2= do not like; 3= neither like nor dislike; 4= like; 5= like it very much.

Moreover, Table 4.6 shows that the appearance of the products had seven significant ($p \leq 0.05$) correlations above r= 0.50. All seven of these correlations were moderate positive correlations and they were presented as follows: (i) I liked the aroma of the product (r= 0.521); (ii) I liked the texture of the product (r= 0.566); (iii) I liked how the product tasted (r= 0.558); (iv) I will eat this product again (r= 0.549); (v) I will purchase this product in a grocery store (r= 0.531); (vi) I will prepare this product for my family (r= 0.550) and lastly, (vii) I will recommend this product to my friends and family (r= 0.516). These moderate positive correlation coefficients indicated how significant the appearance of the product was to the respondents and is a determining factor for future consumption.

Table 4.6: Spearman correlation analysis between the acceptability of the product tasted and the liking of the appearance ($p \leq 0.05$).

Correlations:	I liked the aroma of the product.	I liked the texture of the product.	I liked how the product tasted.	I will eat this food product again.	I will purchase this in a grocery store.	I will prepare this product for my family.	I will recommend this product to my friends and family.
I liked the appearance of the product.	0.521	0.566	0.558	0.549	0.531	0.550	0.516

II. Aroma

According to Table 4.7, just over half (54.4%) (category 4+5) of respondents liked the aroma of the products and a small percentage (8.9%) (category 1+2) did not like the aroma of the products. Some (36.8%) respondents remained neutral, claiming to neither like nor dislike the aroma of the products. The overall mode was category 4, indicating that most of the respondents liked the aroma of the products.

Table 4.7: Respondents liking of the aroma of the products that were tasted.

Question	Nr. of missing values	Category	n=180	%

I liked the aroma of the product.	6	1	1	0.6
		2	15	8.3
		3	66	36.7
		4	69	38.3
		5	29	16.1

Category: 1= do not like at all; 2= do not like; 3= neither like nor dislike; 4= like; 5= like it very much.

Additionally, Table 4.8 shows that liking the aroma of the products presented five significant ($p \leq 0.05$) correlation coefficients above r= 0.50. Four of these correlations were moderate positive correlations and they were presented as follows: (i) I liked the appearance of the product (r= 0.521); (ii) I liked the texture of the product (r= 0.576); (iii) I will purchase this product in a grocery store (r= 0.527); and lastly (iv) I will prepare this product for my family (r= 0.508). One of the five correlations presented a strong (r= 0.611) positive correlation, being ''I liked how the product tasted''. This correlation relationship indicates how important aroma is to the consumer as a determining factor for acceptance of nixtamalized maize products.

Table 4.8: Spearman correlation analysis between the acceptability of the product tasted and the liking of the aroma ($p \leq 0.05$).

Correlations:	I liked the appearance of the product.	I liked the texture of the product.	I liked how the product tasted.	I will purchase this in a grocery store.	I will prepare this product for my family.
I liked the aroma of the product.	0.521	0.576	0.611	0.527	0.508

III. Taste

Table 4.9 shows that just over one-third (38.8%) of the respondents neither liked nor disliked the taste of the products, whereas 52.6% (category 4+5) liked how the product tasted. A low percentage (8.5%, category 1+2) of respondents disliked the taste of the product. The overall mode was category 3, indicating that most of the respondents neither liked nor disliked the taste of the products.

Table 4.9: Respondents liking of the taste of the products that were tasted.

Question	Nr. of missing values	Category	n=175	%
I liked how the product tasted.	11	1	1	0.5
		2	14	8.0
		3	68	38.9

	4	61	34.9
	5	31	17.7

Category: 1= do not like at all; 2= do not like; 3= neither like nor dislike; 4= like; 5= like it very much.

Furthermore, Table 4.10 shows that liking the taste of the products presented eight significant (p ≤ 0.05) correlations above r= 0.50. Five of the eight correlations were moderate positive correlations, and they were presented as follows: (i) I liked the appearance of the product (r= 0.558); (ii) I liked the texture of the product (r= 0.563); (iii) I will prepare this product for my family (r= 0.580); (iv) I will order this product in a restaurant (r= 0.522), and (v) I will recommend this product to my friends and family (r= 0.560). These five correlations indicated how taste directly had a moderate relationship with the five statements mentioned above. Three strong correlations were identified for this statement, namely: (i) I liked aroma of the product (r= 0.611); (ii) I will eat this food product again (r= 0.657) and lastly, I will purchase this product in a grocery store (r= 0.708). In conclusion, aroma had a relationship with the taste of the product, both of which were important attributes to the consumer; in addition, the taste of the product had a strong positive influence on the consumer's willingness to consume the product and purchase it in future.

Table 4.10: Spearman correlation analysis between the acceptability of the product tasted and the liking of the taste (p ≤ 0.05).

Correlations:	I liked the appearance of the product.	I liked the aroma of the product.	I liked the texture of the product.	I will eat this food product again.	I will purchase this in a grocery store.	I will prepare this product for my family.	I will order this product in a restaurant.	I will recommend this product to my friends and family.
I liked how the product tasted.	0.558	0.611	0.563	0.657	0.708	0.580	0.522	0.560

IV. Texture

With regards to texture, more than half (57.8%) (category 4+5) of the respondents liked the texture of the product, while 29.7% remained neutral. A small percentage (12.4%) of respondents did not like the texture of the products. The overall mode for this statement was category 4, indicating that most of the respondents liked the texture of the products.

Table 4.11: Respondents liking of the texture of the products that were tasted.

Question	Nr. of missing values	Category	n=178	%
I liked the texture of the product.	8	1	0	0.0
		2	22	12.4
		3	53	29.8
		4	72	40.4
		5	31	17.4

Category: 1= do not like at all; 2= do not like; 3= neither like nor dislike; 4= like; 5= like it very much.

Texture's likeability had seven significant ($p \leq 0.05$) correlations above r= 0.50. All seven of the correlations were moderate positive correlations and they were presented as follows: (i) I liked the appearance of the product (r= 0.566); (ii) I liked the aroma of the product (r= 0.576); (iii) I liked how the product tasted (r= 0.563); (iv) I will eat this product again (0.560); (v) I will purchase this product in a grocery store (r= 0.584); (vi) I will prepare this product for my family (r= 0.543) and lastly, (vii) I will recommend this product to my friends and family (r= 0.535). The correlations for the texture of the product all showed a moderate positive relationship with the sensory attributes, such as appearance, aroma and taste; this ultimately influenced consumers' attitudes toward future consumption and interrelation recommendation (Table 4.12).

Table 4.12: Spearman correlation analysis between the acceptability of the products tasted and the liking of the texture ($p \leq 0.05$).

Correlations:	I liked the appearance of the product.	I liked the aroma of the product.	I liked how the product tasted.	I will eat this food product again.	I will purchase this in a grocery store.	I will prepare this product for my family.	I will recommend this product to my friends and family.
I liked the texture of the product.	0.566	0.576	0.563	0.560	0.584	0.543	0.535

V. Repeat consumption

According to Table 4.13, most (78.5%) (category 4+5) of the respondents agreed that they would eat the products again, 15.3% of respondents neither disagreed nor agreed with this statement, while a few (6.1%) (category 1+2) disagreed to a repeat consumption of either of these products. The overall mode for this statement was category 4, indicating that most of the respondents agreed that they would eat the products again.

Table 4.13: Respondents' willingness to eat the products again.

Question	Nr. of missing values	Category	n=182	%
I will eat this food product again.	4	1	1	0.6
		2	10	5.5
		3	28	15.4
		4	96	52.7
		5	47	25.8

Category: 1= strongly disagree; 2= disagree; 3= neither disagree nor agree; 4= agree; 5= strongly agree

Furthermore, Table 4.14 shows that the statement had seven significant (p ≤ 0.05) correlations above r= 0.50. Two were moderate positive correlations and they were identified as: (i) I liked the appearance of the product (r= 0.549) and (ii) I liked the texture of the product (r= 0.560). Five were strong positive correlations and they were presented as: (i) I liked how the product tasted (r= 0.657); (ii) I will purchase this product in a grocery store (r= 0.781); (iii) I will prepare this product for my family (r= 0.710); (iv) I will order this product in a restaurant (r= 0.601) and lastly, (v) I will recommend this product to my friends and family (r= 0.693). These strong correlations indicated that taste had a strong relationship with consumers' inclination to eat the product again and motivation for future purchasing, self-preparation and recommendations to peers.

Table 4.14: Spearman correlation analysis between the acceptability of the products tasted and the willingness to eat the products again (p ≤ 0.05).

Correlation:	I liked the appearance of the product.	I liked the texture of the product.	I liked how the product tasted.	I will purchase this in a grocery store.	I will prepare this product for my family.	I will order this product in a restaurant.	I will recommend this product to my friends and family.
I will eat this food product again.	0.549	0.560	0.657	0.781	0.710	0.601	0.693

VI. Purchasing the products in a grocery store

Table 4.15 shows that most of the respondents (60.8%) (category 4+5) agreed to purchasing the products in a grocery store, 22.0% neither disagreed nor agreed to this statement, while 17.2% (category 1+2) disagreed to making a purchase in a grocery store. The overall mode for this statement was 4, which indicates that most of the respondents agreed to purchasing the products in a grocery store.

Table 4.15: Respondents' willingness to purchase the products in a grocery store.

Question	Nr. of missing values	Category	n=181	%
I will purchase this product in a grocery store.	5	1	3	1.7
		2	28	15.5
		3	40	22.0
		4	69	38.1
		5	41	22.7

Category: 1= strongly disagree; 2= disagree; 3= neither disagree nor agree; 4= agree; 5= strongly agree

Moreover, Table 4.16 shows that eight significant ($p \leq 0.05$) correlations above r= 0.50 were presented for the statement, "I will purchase the product in a grocery store". Three were moderate positive correlations and were identified as: (i) I liked the appearance of the product (r= 0.531); (ii) I liked the aroma of the product (r= 0.527) and (iii) I liked the texture of the product (r= 0.584). Five were strong positive correlations, and they were presented as: (i) I liked how the product tasted (r= 0.708); (ii) I will eat this food product again (r= 0.781); (iii) I will prepare this food product for my family (r= 0.786); (iv) I will order this product in a restaurant (r= 0.739) and lastly, (v) I will recommend this product to my friends and family (r= 0.802). The strong correlations showed the contributors to the consumer wanting and willingness to purchase the product in a grocery store.

Table 4.16: Spearman correlation analysis between the acceptability of the products tasted and the willingness to purchase the products in a grocery store ($p \leq 0.05$).

Correlation:	I liked the appearance of the product.	I liked the aroma of the product.	I liked the texture of the product.	I liked how the product tasted.	I will eat this food product again.	I will prepare this product for my family.	I will order this product in a restaurant.	I will recommend this product to my friends and family.
I will purchase this in a grocery store.	0.531	0.527	0.584	0.708	0.781	0.786	0.739	0.802

VII. Preparing the products for family

According to Table 4.17, more than half of the respondents (57.2%) (category 4+5) agreed to preparing either of the products at home for their families, while 21.7% neither disagreed nor agreed to this statement. However, 21.1% (category 1+2) disagreed that they would prepare the products themselves. The overall mode for this statement also remains 4, indicating that most of the respondents agreed that they would prepare the products themselves at home.

Table 4.17: Respondents' willingness to prepare the products for their families.

Question	Nr. of missing values	Category	n=180	%
I will prepare this product for my family.	6	1	4	2.2
		2	34	18.9
		3	39	21.7
		4	69	38.3
		5	34	18.9

Category: 1= strongly disagree; 2= disagree; 3= neither disagree nor agree; 4= agree; 5= strongly agree

In addition, Table 4.18 shows that for the statement, "I will prepare this product for my family", eight significant ($p \leq 0.05$) correlations above r= 0.50 were presented. Four of the correlations were moderate positive correlations and were: (i) I liked the appearance of the product (r= 0.550); (ii) I liked the aroma of the product (r= 0.508); (iii) I liked the texture of the product (r= 0.543) and (iv) I liked how the product tasted (r= 0.580). Four strong positive correlations were also presented: (i) I will eat this food product again (r= 0.710); (ii) I will purchase this product in a grocery store (r= 0.786); (iii) I will order this product in a restaurant (r= 0.716) and lastly, (iv) I will recommend this product to my friends and family (r= 0.731). The statement, ''I will prepare this product for my family" had a ripple effect on the consumer's attitude toward continuous future consumption of this nixtamalized maize product.

Table 4.18: Spearman correlation analysis between the acceptability of the products tasted and the willingness to prepare the products for their families ($p \leq 0.05$).

Correlation:	I liked the appearance of the product.	I liked the aroma of the product.	I liked the texture of the product.	I liked how the product tasted.	I will eat this food product again.	I will purchase this product in a grocery store.	I will order this product in a restaurant.	I will recommend this product to my friends and family.

I will prepare this product for my family.	0.550	0.508	0.543	0.580	0.710	0.786	0.716	0.731

VIII. Ordering the products in a restaurant

Table 4.19 reveals that a small majority (45.5%) (category 4+5) agreed that they would order either of the products in a restaurant, while 20.8% neither disagreed nor agreed to this statement. However, 33.7% (category 1+2) disagreed with the possibility of ordering any of the products in a restaurant, resulting in the largest disagreement of all the statements listed. The overall mode for this statement was 4, indicating that most of the respondents agree ordering the products in a restaurant.

Table 4.19: Respondents' willingness to order the products in a restaurant.

Question	Nr. of missing values	Category	n=178	%
I will order this product in a restaurant.	8	1	12	6.8
		2	48	26.9
		3	37	20.8
		4	53	29.8
		5	28	15.7

Category: 1= strongly disagree; 2= disagree; 3= neither disagree nor agree; 4= agree; 5= strongly agree

Furthermore, in Table 4.20, the statement, "I will order this product in a restaurant", had five significant ($p \leq 0.05$) correlations above r= 0.50. The statement ''I liked how the product tasted'' had a moderate positive correlation (r= 0.522). Four strong positive correlations were presented, namely: (i) I will eat this food product again (r= 0.601); (ii) I will purchase this product in a grocery store (r= 0.739); (iii) I will prepare this product for my family (r= 0.716) and lastly, (iv) I will recommend this product to friends and family (r= 0.776). The above correlations indicated positive consumer attitudes toward continuous future consumption of this nixtamalized maize product.

Table 4.20: Spearman correlation analysis between the acceptability of the products tasted and the willingness to order the products in a restaurant ($p \leq 0.05$).

Correlation:	I liked how the product tasted.	I will eat this food product again.	I will purchase this product in a grocery store.	I will prepare this product for my family.	I will recommend this product to my friends and family.

I will order this product in a restaurant.	0.522	0.601	0.739	0.716	0.776	

IX. Recommending the products to friends and family

When asked if the respondents would recommend the products to family and friends, most (62.2%) (category 4+5) of the respondents agreed to this statement, 21.7% neither disagreed nor agreed, while 16.1% (category 1+2) disagreed. The overall mode for this statement was 4, indicating that most of the respondents agreed that they would recommend the products to family and friends (Table 4.21).

Table 4.21: Respondents' willingness to recommend the products to friends and family.

Question	Nr. of missing values	Category	n=180	%
I will recommend this product to my friends and family.	6	1	4	2.2
		2	25	13.9
		3	39	21.7
		4	77	42.8
		5	35	19.4

Category: 1= strongly disagree; 2= disagree; 3= neither disagree nor agree; 4= agree; 5= strongly agree

Additionally, Table 4.22 shows that seven significant ($p \leq 0.05$) correlations above r= 0.50 for the statement, ''I will recommend this product to my friends and family", were identified. Three moderate positive correlations were presented, namely: (i) I liked the appearance of the product (r= 0.516); (ii) I liked the texture of the product (r= 0.535) and (iii) I liked how the product tasted (r= 0.560). Four strong positive correlations were presented, namely: (i) I will eat this food product again (r= 0.693); (ii) I will purchase this product in a grocery store (r= 0.802); (iii) I will prepare this product for my family (r= 0.731) and lastly, I will order this product in a restaurant (r= 0.776). These correlations indicated why the respondents would recommend this nixtamalized product to their friends and family.

Table 4.22: Spearman correlation analysis between the acceptability of the products tasted and the willingness to recommend the products to friends and family ($p \leq 0.05$).

Correlation:	I liked the appearance of the product.	I liked the texture of the product.	I liked how the product tasted.	I will eat this food product again.	I will purchase this in a grocery store.	I will prepare this product for my family.	I will order this product in a restaurant.

I will recommend this product to my friends and family.	0.516	0.535	0.560	0.693	0.802	0.731	0.776

4.5.3 Knowledge and awareness of the safety of maize

This section explored the respondent's degree of knowledge and awareness of different varieties of maize, and their safety and storage requirements (Questions 3.1 to 3.6).

I. Exclusively consuming white maize

According to Table 4.23, most respondents (62.7%) (category 1+2) disagreed with the statement, "I will only eat white maize." The results indicated that many consumers were open to consuming a wide variety of maize of colours different from white maize. The results for those respondents who neither disagreed nor agreed remained the lowest (15.9%), while those who agreed to only eat white maize, were at a combined percentage of 21.4% (category 4+5). The overall mode for this statement was 2, indicating that most of the respondents disagreed with the statement.

Table 4.23: Respondents who only eat white maize.

Question	Nr. of missing values	Category	n=182	%
I only eat white maize.	4	1	33	18.1
		2	81	44.6
		3	29	15.9
		4	27	14.8
		5	12	6.6

Category: 1= strongly disagree; 2= disagree; 3= neither disagree nor agree; 4= agree; 5= strongly agree.

II. Consuming other coloured maize in addition to white and yellow maize

Table 4.24 shows that just over three-fourths (77.2%) (category 4+5) of the respondents agreed that they would eat other coloured maize, in addition to white and yellow maize. The results for those who neither disagreed nor agreed with this statement were 16.7%. A low percentage of the respondents (16.1%) (category 1+2) disagreed with being open to eating maize of other colours, in addition to white and yellow maize. The overall mode was 4, indicating that most of the respondents agreed with the statement.

Table 4.24: Respondents who are willing to eat maize of other colours, in addition to white and yellow maize.

Question	Nr. of missing values	Category	n=180	%
I will eat maize of others colours, in addition to white and yellow maize.	6	1	3	1.7
		2	8	4.4
		3	30	16.7
		4	101	56.1
		5	38	21.1

Category: 1= strongly disagree; 2= disagree; 3= neither disagree nor agree; 4= agree; 5= strongly agree.

Furthermore, Table 4.25 shows that in the statement, "I will eat maize of other colours in addition to white and yellow maize", only one significant (p ≤ 0.05) correlation above r= 0.50 was identified, namely: I will eat and prepare any colour maize if I know that they are safe to eat (r= 0.510); this presented a moderate positive correlation. This correlation indicated that once respondents have acquired sufficient knowledge on the safety of maize other than white and yellow, they would be willing to consume it.

Table 4.25: Spearman correlation analysis between the knowledge and safety of maize, and the willingness to eat maize of other colours, in addition to white and yellow maize (p ≤ 0.05).

Correlation:	I will eat and prepare any colour maize if I know that they are safe to eat.
I will eat maize of other colours in addition to white and yellow maize.	0.510

III. Safety of white and yellow maize

According to Table 4.26, the majority (78.6%) (category 4+5) of respondents agreed that both white and yellow dried maize were safe to eat. Seventeen-point-six percent (17.6%) of respondents neither disagreed nor agreed with the statement, while only 3.8% (category 1+2) of the respondents disagreed. The overall mode was 4, indicating that most of the respondents agreed with the statement.

Table 4.26: Respondents who agree or disagree that both white and yellow maize are safe to eat.

Question	Nr. of missing values	Category	n=182	%
Both white and yellow dried maize are safe to eat.	4	1	2	1.1
		2	5	2.7
		3	32	17.6
		4	79	43.4
		5	64	35.2

Category: 1= strongly disagree; 2= disagree; 3= neither disagree nor agree; 4= agree; 5= strongly agree.

Table 4.27 shows that the statement, ‘’Both white and yellow dried maize are safe to eat”, only had one significant ($p \leq 0.05$) correlation above r= 0.50. Namely: I will eat and prepare any colour maize if I know that they are safe to eat (r= 0.575).

Table 4.27: Spearman correlation analysis between the knowledge and safety of maize, and respondents who agree or disagree that both white and yellow maize are safe to eat ($p \leq 0.05$).

Correlation:	I will eat and prepare any colour maize if I know that they are safe to eat.
Both white and yellow maize are safe to eat.	0.575

IV. Consuming and preparing any colour maize with the knowledge that it is safe to eat

The results for the respondent’s willingness to prepare any colour maize, if they had the knowledge that it was safe to eat is shown in Table 4.28. A combined percentage of 92.3% (category 4+5) agreed that they would prepare any colour maize that would be safe to eat. The results for those who neither disagreed nor agreed with this statement were 3.9%, while 3.8% (category 1+2) of the respondents disagreed with this statement. The overall mode was 4, indicating that most of the respondents agreed with the statement.

Table 4.28: Respondents willing to eat and prepare any colour maize that are safe to eat.

Question	Nr. of missing values	Category	n=181	%
I will eat and prepare any colour maize if I know that they are safe to eat.	5	1	1	0.5
		2	6	3.3
		3	7	3.9
		4	86	47.5
		5	81	44.8

Category: 1= strongly disagree; 2= disagree; 3= neither disagree nor agree; 4= agree; 5= strongly agree.

V. Safety of maize

Table 4.29 shows the results of the respondent’s eagerness to be more informed about a process that can improve the safety of stored maize. The majority of respondents (85.7%) (category 4+5) agreed with this statement. The results for those who neither disagreed nor agreed with this statement were 8.8%, whereas 5.5% (category 1+2) disagreed. The overall mode was 4, indicating that most of the respondents agreed with the statement.

Table 4.29: Respondents who want to know of a process that will make stored maize safe to eat.

Question	Nr. of missing values	Category	n=181	%
I want to know more about a process that will make stored maize safe to eat.	5	1	2	1.1
		2	8	4.4
		3	16	8.8
		4	91	50.3
		5	64	35.4

Category: 1= strongly disagree; 2= disagree; 3= neither disagree nor agree; 4= agree; 5= strongly agree.

Additionally, Table 4.30 shows the results of the respondent's interest in learning about maize that would be safe to eat, after being stored for a long time. The majority of the respondents (87.4%) (category 4+5) agreed with this statement. The results for those who neither disagreed nor agreed with this statement, were 8.7%, whereas 3.9% (category 1+2) disagreed. The overall mode was 4, indicating that most of the respondents agreed with the statement.

Table 4.30: Respondents who are interested in learning about maize that is safe to eat after being stored for a long time.

Question	Nr. of missing values	Category	n=183	%
I am interested in learning about maize that is safe to eat after being stored for a long time.	3	1	2	1.2
		2	5	2.7
		3	16	8.7
		4	91	49.7
		5	69	37.7

Category: 1= strongly disagree; 2= disagree; 3= neither disagree nor agree; 4= agree; 5= strongly agree.

Both above-mentioned statements: "I want to know more about a process that will make stored maize safe to eat'' and ''I am interested in learning about maize that is safe to eat after being stored for a long time'', a strong positive correlation was identified (r= 0.818). This indicated that respondents wanted to learn more about ways to make stored maize safer, to eat for long periods.

Table 4.31: Spearman correlation analysis between the knowledge and safety of maize, and respondents who want to know of a process that will make stored maize safe to eat (p ≤ 0.05).

Correlation:	I am interested in learning about maize that is safe to eat after being stored for a long time.

I want to know more about a process that will make stored maize safe to eat.	0.818

According to the above-mentioned findings, most of the respondents were more open to consuming maize of different varieties (colour). This was proved differently in a study by Pillay, Siwela and Veldman (2011), where respondents aged three to 55 years differed in their preferences for yellow or white maize: pre-schoolers preferred yellow maize over white, while primary schoolers, high schoolers, and adults preferred white maize. They concluded that the preference for white maize food products by primary schoolers, teenagers and adults was due to their familiarity with the grain, since they had been consuming it for a longer period than the pre-schoolers. Furthermore, the majority of respondents in the current study were willing to gain knowledge of processes that could improve the safety of maize.

4.5.4 Consumer awareness of maize as a food source

This section of the questionnaire explored the respondents awareness of maize of other colours as a food source as well as factors that would influence their willingness to consumer nixtamalized maize (Questions 4.1 to 4.11).

I. Seen maize of different colours in person

As presented in Table 4.32, 26.5% of the respondents had never seen maize of different colours in person, whereas 15.1% claimed to have seen maize of different colours more than once in the past year. The results for the remaining respondents were as follows: at least once in my life (23.8%); a few times in my life (22.2%); and, at least once during the past year (12.4%). The overall mode was 1, indicating that most of the respondents have never seen maize of different colours in person.

Table 4.32: Respondents who have seen maize of different colours in person.

Question	Nr. of missing values	Category	n=185	%
I have seen maize of different colours in person.	1	1	49	26.5
		2	44	23.8
		3	41	22.2
		4	23	12.4
		5	28	15.1

Category: 1= never; 2= at least once in my life; 3= a few times in my life; 4= At least once during the past year; 5= More than once in the past year

Moreover, Table 4.33 shows that the statement, "I have seen maize of different colours in person", presented three significant ($p \leq 0.05$) correlations above r= 0.50. Two of these correlations presented a moderate positive relationship, namely: (i) I have eaten meals/food with maize of other colours other than white maize (r= 0.586) and (ii) I have cultivated maize of other colours for human consumption (r= 0.554).

Table 4.33: Spearman correlation analysis between consumers' awareness of maize as a food source and respondents who have seen maize of different colours in person ($p \leq 0.05$).

Correlation:	I have prepared meals/food with maize kernels/products with different colours.	I have eaten meals/food with maize of other colours than white maize.	I have cultivated maize of other colours for human consumption.
I have seen maize of different colours in person.	0.609	0.586	0.554

II. Prepared meals with maize of different colours

The results for the statement concerning the preparation of meals, using different coloured maize were presented in Table 4.34 as follows: never (45.4%); at least once in my life (19.5%); a few times in my life (16.8%); at least once during the past year (7.6%) and more than once in the past year (10.8%). The overall mode was 1, indicating that most of the respondents had never prepared meals with maize kernels of different colours.

Table 4.34: Respondents who have prepared meals with maize kernels/products of different colours.

Question	Nr. of missing values	Category	n=185	%
I have prepared meals/food with maize kernels/products of different colours.	1	1	84	45.4
		2	36	19.5
		3	31	16.8
		4	14	7.5
		5	20	10.8

Category: 1= never; 2= at least once in my life; 3= a few times in my life; 4= At least once during the past year; 5= More than once in the past year

Additionally, Table 4.35 shows that for the statement, ‘’I have prepared meals/food with maize kernels/products of different colours”, three significant ($p \leq 0.05$) correlations above r= 0.50 were identified. All three correlations had a strong positive relationship with the above statement. The correlation of ‘’I have seen maize of different colours in person” with the above-mentioned statement had a correlation coefficient degree of r= 0.609. Additionally, the following two statements also presented a correlation coefficient degree within the strong range (0.60 to 0.79): “I have eaten meals/food with maize of other colours other than white maize” (r= 0.733) and “I have cultivated maize of other colours for human consumption” (r= 0.658). These correlations indicated that respondents had prepared maize of different colours, because they ate and cultivated maize of different colours.

Table 4.35: Spearman correlation analysis between consumers’ awareness of maize as a food source and respondents who have prepared meals with maize kernels/products of different colours ($p \leq 0.05$).

Correlation:	I have seen maize of different colours in person.	I have eaten meals/food with maize of other colours than white maize.	I have cultivated maize of other colours for human consumption.
I have prepared meals/food with maize kernels/products with different colours.	0.609	0.733	0.658

III. Consumed meals with maize of other colours than white maize

For the statement, “I have eaten meals/food with maize of other colours than white maize”, respondents showed the following results (Table 4.36): never (68.1%); at least once in my life (11.0%); a few times in my life (11.0%); at least once during the past year (3.3%) and more than once in the past year (6.6%). The overall mode was 3, indicating most of the respondents have eaten meals with maize of other colours other than white maize a few times in their lives.

Table 4.36: Respondents who have eaten meals with maize of other colours than white maize.

Question	Nr. of missing values	Category	n=185	%
I have eaten meals/food with maize of other colours than white maize.	1	1	48	25.9
		2	39	21.1
		3	52	28.1
		4	14	7.6

		5	32	17.3

Category: 1= never; 2= at least once in my life; 3= a few times in my life; 4= At least once during the past year; 5= More than once in the past year

Moreover, three significant ($p \leq 0.05$) correlations above r= 0.50 were identified for the statement, ‘’I have eaten meals/food with maize of other colours other than white maize” (Table 4.37). Two of the correlations rendered moderate positive correlations: “I have seen maize of different colours” (r= 0.586) and “I have cultivated maize of different colours for human consumption” (0.570). Lastly, the statement, ‘’I have prepared meals/food with maize kernels/products of different colours’’ presented a correlation coefficient degree of r= 0.733. These correlations pointed out that participants who had eaten different coloured maize, had more likely prepared and grown different coloured maize themselves.

Table 4.37: Spearman correlation analysis between consumers’ awareness of maize as a food source and respondents who have eaten meals with maize of other colours than white maize ($p \leq 0.05$).

Correlation	**I have seen maize of different colours.**	**’I have prepared meals/food with maize kernels/products of different colours.**	**I have cultivated maize of other colours for human consumption.**
I have eaten meals/food with maize of other colours than white maize.	0.586	0.733	0.570

IV. Cultivation of other coloured maize for human consumption

Respondents were asked whether they had cultivated maize of other colours for human consumption. Table 4.38 presented the results as follows: never (68.1%); at least once in my life (11.0%); a few times in my life (11.0%); at least once during the past year (3.3%) and more than once in the past year (6.6%). The overall mode was 1, indicating that most of the respondents had never cultivated maize of other colours for human consumption.

Table 4.38: Respondents who have cultivated maize of other colours for human consumption.

Question	**Nr. of missing values**	**Category**	**n=182**	**%**
I have cultivated maize of other colours for human consumption.	4	1	124	68.1
		2	20	11.0
		3	20	11.0

	4	6	3.3
	5	12	6.6

Category: 1= never; 2= at least once in my life; 3= a few times in my life; 4= At least once during the past year; 5= More than once in the past year

Additionally, three significant ($p \leq 0.05$) correlations above r= 0.50 were recognised for the statement, ‘’I have cultivated maize of other colours for human consumption” (Table 4.39). Two were moderate positive correlations and one was strong positive correlations, namely: (i) “I have eaten meals/food with maize of other colours other than white maize” (r= 0.570); (ii) “I have prepared meals/food with maize kernels/products of different colours” (r= 0.658) and (iii) “I have seen maize of different colours” (r= 0.554). These correlations indicated that if a participant had cultivated different colour maize they would most likely have prepared and eaten maize of different colours.

Table 4.39: Spearman correlation analysis between consumers’ awareness of maize as a food source and respondents who have cultivated maize of other colours for human consumption ($p \leq 0.05$).

Correlation:	I have eaten meals/food with maize of other colours other than white maize.	I have prepared meals/food with maize kernels/products of different colours.	I have seen maize of different colours.
I have cultivated maize of other colours for human consumption.	0.570	0.658	0.554

To sum up consumers’ awareness of different coloured maize (Table 4.32 to 4.39), the majority of respondents had no or little contact with coloured maize in person; however, some of the respondents had seen and eaten maize of other colours than white maize, a few times in their lives.

V. Respondents who will only eat nixtamalized maize products if they are given it for free

As presented in Table 4.40, the results for respondents willing to only eat nixtamalized maize, if they were given it for free, were as follows: more than a quarter (30.2%) (category 1+2) of respondents disagreed with this statement; 28.6% neither disagreed nor agreed; and 41.1% (category 4+5) of respondents agreed. The overall mode was 3, indicating that most of the respondents neither disagreed nor agreed with this statement. On the contrary, Linzbach, Inman, and Nikolova, (2019), revealed that products that are given to consumers to test for free, can affect their future purchasing behaviour.

Table 4.40: Respondents who will only eat nixtamalized maize products if they are given it for free.

Question	Nr. of missing values	Category	n=185	%
...these products are given to me for free.	1	1	13	7.1
		2	43	23.2
		3	53	28.6
		4	48	26.0
		5	28	15.1

Category: 1= strongly disagree; 2= disagree; 3= neither disagree nor agree; 4= agree; 5= strongly agree

VI. Respondents willingness to eat nixtamalized maize dependent on their knowledge of its health benefits

Table 4.41 shows the results for the statement, "...I have more knowledge about the health benefits of nixtamalized maize than I do at present.". The results are shown as follows: a few (15.6%) (category 1+2) of the respondents disagreed with this statement; 19.0% neither disagreed nor agreed; and the majority (65.4%) (category 4+5) of respondents agreed with this statement. The overall mode was 4, indicating that most of the respondents agreed that their knowledge of the health benefits of nixtamalized maize would serve as motivation for them to consume it. This is supported by Piha *et al.* (2018), who stated that reliable scientific-based information, about novel foods, could influence consumers' beliefs and acceptance of new food products.

Table 4.41: Respondents who will only eat nixtamalized maize products if they have more knowledge about the health benefits.

Question	Nr. of missing values	Category	n=185	%
...I have more knowledge about the health benefits of nixtamalized maize than I do at present.	1	1	5	2.7
		2	24	12.9
		3	35	19.0
		4	82	44.3
		5	39	21.1

Category: 1= strongly disagree; 2= disagree; 3= neither disagree nor agree; 4= agree; 5= strongly agree

VII. Respondents who will only eat nixtamalized maize products if it is available in a local supermarket

According to Si, Scott and McCordic (2019), the location of food sources is a critical indicator of food accessibility for consumers; thus, the statement, "...it is available for purchase in my local supermarket.", Table 4.42 presented the following results: a few (15.7%) (category 1+2) disagreed with this statement; 19.5% neither disagreed nor agreed; and the majority (64.8%) (category 4+5) of the respondents agreed with this statement. The overall mode was 4, indicating that most of the respondents agreed that the availability of nixtamalized maize in supermarkets would increase their purchase and consumption of it.

Table 4.42: Respondents who will only eat nixtamalized maize products if it is available in a local supermarket.

Question	Nr. of missing values	Category	n=185	%
...it is available for purchase in my local supermarket.	1	1	9	4.9
		2	20	10.8
		3	36	19.5
		4	90	48.6
		5	30	16.2

Category: 1= strongly disagree; 2= disagree; 3= neither disagree nor agree; 4= agree; 5= strongly agree

VIII. Respondents who will only eat nixtamalized maize products if their friends and family eat it too

For the statement, "...my friends and family use nixtamalized maize products." The following results were presented in Table 4.43: a few (26.9%) (category 1+2) of the respondents disagreed with the statement; 24.7% of respondents neither disagreed nor agreed, while almost half (48.4%) (category 4+5) of respondents agreed with the statement. The overall mode was 4, indicating that most of the respondents agreed that the consumption of nixtamalized maize by peers would increase their willingness to eat it as well. East, Hammond and Lomax (2008) found that positive word of mouth can positively influence a consumer's decision to buy and/or use a product.

Table 4.43: Respondents who will only eat nixtamalized maize products if their friends and family eat it too.

Question	Nr. of missing values	Category	n=182	%

...my friends and family use nixtamalized maize products.	4	1	14	7.7
		2	35	19.2
		3	45	24.7
		4	65	35.8
		5	23	12.6

Category: 1= strongly disagree; 2= disagree; 3= neither disagree nor agree; 4= agree; 5= strongly agree

IX. Respondents who will only eat nixtamalized maize products if the flour is cheaper

The results for the statement, "...nixtamalized maize meal is cheaper than other maize meal or maize kernels.", were presented in Table 4.44 as follows: only a few (14.8%) (category 1+2) of the respondents disagreed with this statement; almost half (49.7%) neither disagreed nor agreed while 35.5% agreed. The overall mode was 3, indicating that most of the respondents were neutral on this statement.

Table 4.44: Respondents who will only eat nixtamalized maize products if the flour is cheaper than other maize meal or kernels.

Question	Nr. of missing values	Category	n=183	%
...nixtamalized maize meal is cheaper than other maize meal or maize kernels.	3	1	2	1.1
		2	25	13.7
		3	91	49.7
		4	47	25.7
		5	18	9.8

Category: 1= strongly disagree; 2= disagree; 3= neither disagree nor agree; 4= agree; 5= strongly agree

Furthermore, Table 4.45 shows that ''…nixtamalized maize meal is cheaper than other maize meal or maize kernels'' had one significant ($p \leq 0.05$) positive strong correlation above r= 0.50 with the statement ''…nixtamalized maize meal is similarly priced compared to other maize meal'' (r= 0.644). The correlation between the two indicated that respondents would only consume nixtamalized maize products if maize meal were cheaper or more or less priced on the same scale, compared to other market-related maize meal.

Table 4.45: Spearman correlation analysis between consumers' awareness of maize as a food source and respondents who will only eat nixtamalized maize products if the maize meal is cheaper than other maize meal or kernels ($p \leq 0.05$).

Correlation:	…nixtamalized maize meal is similarly priced compared to other maize meal.

...nixtamalized maize meal is cheaper than other maize meal or maize kernels.	0.644

X. Respondents who will only eat nixtamalized maize products if nixtamalized maize meal is similarly priced compared to other maize meal

According to Table 4.46, the results for the statement, "...nixtamalized maize meal is similarly priced compared to other maize meal.", respondents showed the following results: a small number (7.0%) (category 1+2) of respondents disagreed; almost half (49.5%) of respondents neither disagreed nor agreed, while 43.5% (category 4+5) agreed with the statement. The overall mode was 3, indicating that most of the respondents neither disagreed nor agreed with the statement.

Table 4.46: Respondents who will only eat nixtamalized maize products if the maize meal is similarly priced compared to other maize meal.

Question	Nr. of missing values	Category	n=184	%
...nixtamalized maize meal is similarly priced compared to other maize meal.	2	1	2	1.1
		2	11	5.9
		3	91	49.5
		4	65	35.3
		5	15	8.2

Category: 1= strongly disagree; 2= disagree; 3= neither disagree nor agree; 4= agree; 5= strongly agree

XI. Respondents who will only eat nixtamalized maize flour when they do not have access to any other food

According to Table 4.47, the statement, "...when I do not have access to any other food.", the following results were presented: less than a quarter (21.7%) (category 1+2) of respondents disagreed; 27.2% neither disagreed nor agreed, while just over a half (51.1%) (category 4+5) of respondents agreed with the statement. The overall mode was 4, indicating that most of the respondents agreed that they would eat nixtamalized maize if they did not have access to other food.

Table 4.47: Respondents who will only eat nixtamalized maize products if they do not have access to any other food.

Question	Nr. of missing values	Category	n=184	%
...when I do not have access to any other food.	2	1	8	4.3
		2	32	17.4

		3	50	27.2
		4	62	33.7
		5	32	17.4

Category: 1= strongly disagree; 2= disagree; 3= neither disagree nor agree; 4= agree; 5= strongly agree

To draw a conclusion, the results in Table 4.40 to 4.47 showed that respondents would be willing to eat nixtamalized maize, based on their available knowledge of the process, its availability, peer consumption and lack of options for other food sources. However, respondents remained neutral on other statements concerning nixtamalized maize products being given for free and it being cheaper or similarly priced to existing products, available in the market.

4.5.5 Knowledge and awareness of new food products and trends

The following section comprises of the results of how important respondents found certain considerations when deciding to introduce a new food item into their diet (Questions 5.1 to 5.6). Additionally, the results for how often respondents try out new food products, ingredients, recipes and trends are also discussed below (Questions 5.7 to 5.14).

I. Health benefits of the food item

The results for the statement, “The health benefits of the food item.”, were presented Table 4.48 as follows: a few (1.6%) of the respondents did not consider this statement important; a small amount (7.6%) of respondents found it neither unimportant nor important, while the majority (90.8%) (category 4+5) of respondents found it important. The overall mode was 5, indicating that most of the respondents considered the health benefits of a new food item extremely important. This was supported by an experimental study by Bialkova, Sasse and Fenko (2016), where the packaging of chips was marketed with health-promoting benefits, such as 30% less fat, 30% less sugar, while a third option had no health claims. The results showed that the perception of healthier products, increased the buying intention.

Table 4.48: Importance of health benefits of a new food item to the respondents.

Question	Nr. of missing values	Category	n=185	%
The health benefits of the food item.	1	1	0	0
		2	3	1.6
		3	14	7.6
		4	81	43.8
		5	87	47.0

Category: 1= not important at all; 2= not important; 3= neither unimportant nor important; 4= important and 5= extremely important.

According to Table 4.49, one significant ($p \leq 0.05$) moderate positive correlation above r= 0.50 between the health benefits of the food item and the general availability of the food item (r= 0.523) was observed.

Table 4.49: Spearman correlation analysis between the knowledge and awareness of new food products and trends, and the importance of health benefits of a new food item to the respondents ($p \leq 0.05$).

Correlation:	The general availability of the food item
The health benefits of the food item.	0.523

II. General availability of the food item

Table 4.50 shows the results for the statement, "The general availability of the food item.". The results are as follows: only 1.1% found it not important; a small percentage (9.8%) of respondents found it neither unimportant nor important, while the majority (89.1%) (category 4+5) of respondents found the statement important. The overall mode was 4, indicating that most of the respondents consider the statement important.

Table 4.50: Importance of the availability of a new food to the respondents.

Question	Nr. of missing values	Category	n=183	%
The general availability of the food item.	3	1	0	0
		2	2	1.1
		3	18	9.8
		4	99	54.1
		5	64	35.0

Category: 1= not important at all; 2= not important; 3= neither unimportant nor important; 4= important and 5= extremely important.

III. Trendiness of the food item

According to Table 4.51, "The trendiness of the food item.", presented the following results: almost a quarter (22.7%) (category 1+2) of respondents found it not important; 33.7% found it neither unimportant nor important; however almost half (43.6%) (category 4+5) of respondents found it important. The overall mode was 3, indicating that some respondents found the trendiness of a food item neither unimportant nor important.

Table 4.51: Importance of the trendiness of a new product to the respondents.

Question	Nr. of missing values	Category	n=181	%
The trendiness of the food item.	5	1	11	6.1
		2	30	16.6
		3	61	33.7
		4	50	27.6
		5	29	16.0

Category: 1= not important at all; 2= not important; 3= neither unimportant nor important; 4= important and 5= extremely important.

Furthermore, "the trendiness of the food item", had one significant ($p \leq 0.05$) correlation above r= 0.50 was presented, namely "Promotion of the food item. For example: being given free samples to try."; this statement presented a correlation coefficient degree of r= 0.513. This indicated that free samples of a new food item correlated moderately with the trendiness of the food item (Table 4.52).

Table 4.52: Spearman correlation analysis between the knowledge and awareness of new food products and trends, and the importance of the trendiness of a new food item to the respondents ($p \leq 0.05$).

Correlation:	***Promotion of the food item. For example: being given free samples to try***
The trendiness of the food item.	0.513

IV. Importance of new food products being similarly priced to existing ones

The results for the statement, "The price of the food item is similar when compared to other products.", was presented in Table 4.53 as follows: a small percentage (2.1%) (category 1+2) of respondents found this statement unimportant; 20.3% found it neither unimportant nor important, whereas the majority (77.6%) (category 4+5) found the statement important. The overall mode was 4, indicating that most of the respondents found the statement important. In a paper published by Xie *et al*. (2015), mixed method research was carried out to determine consumers' purchasing decisions of organic foods, in Eastern China. The mixed methods design focused on many variables that play a role in consumers' purchasing decisions, price being one of them. A large majority of the respondents (84.8%) said they would be willing to purchase organic food, if they had more income, whereas two of the respondents said they would only purchase organic products if they were similarly priced as conventional products.

Table 4.53: Importance of new food products being similarly priced compared to other products.

Question	Nr. of missing values	Category	n=182	%
The price of the food item is similar when compared to other products.	4	1	1	0.5
		2	3	1.6
		3	37	20.3
		4	83	45.6
		5	58	32.0

Category: 1= not important at all; 2= not important; 3= neither unimportant nor important; 4= important and 5= extremely important.

V. Importance of a new food item being cheaper when compared to similar items

In the case of the statement, "The price of the new food item is cheaper when compared to other similar products.", the results were presented in Table 4.54 as follows: a few (8.2%) (category 1+2) of the respondents found the statement not important; 27.7% of respondents found it neither unimportant nor important, whereas most (64.1%) (category 4+5) of respondents consider it important. The overall mode was 4, indicating that most of the respondents found the importance of the affordability of a new food item important. The importance of affordability is supported by the above-mentioned study by Xie *et al*. (2015).

Table 4.54: Importance of new food products being cheaper when compared to other similar products.

Question	Nr. of missing values	Category	n=184	%
The price of the new food item is cheaper when compared to other similar products.	2	1	2	1.1
		2	13	7.1
		3	51	27.7
		4	60	32.6
		5	58	31.5

Category: 1= not important at all; 2= not important; 3= neither unimportant nor important; 4= important and 5= extremely important.

For the statement, "the price of the new food item is cheaper when compared to other products", two significant ($p \leq 0.05$) correlations above $r= 0.50$ were identified. The two correlations were both moderately positive, namely: (i) “Promotion of the food item. For example: being given free samples to try” (r= 0.506) and (ii) “The use of the food item by friends and family” (r= 0.504) (Table 4.55).

Table 4.55: Spearman correlation analysis between the knowledge and awareness of new food products and trends, and the importance of new food products being cheaper when compared to other similar products ($p \leq 0.05$).

Correlation:	Promotion of the food item. For example: being given free samples to try.	The use of the food item by friends and family.
The price of the new food item is cheaper when compared to other products.	0.506	0.504

VI. Importance of the promotion of the food item

The results for the statement, “Promotion of the food item. For example: being given free samples to try.”, showed the following results: a small percentage (9.2%) (category 1+2) of respondents found this consideration not important; just over a quarter (26.6%) of respondents consider it neither unimportant nor important; however, most (64.2%) (category 4+5) of the respondents found it important. The overall mode was 4, indicating that the promotion of a new food item was considered important to most of the respondents.

Table 4.56: Importance of the promotion of a food item.

Question	Nr. of missing values	Category	n=184	%
Promotion of the food item. For example: being given free samples to try.	2	1	4	2.2
		2	13	7
		3	49	26.6
		4	73	39.7
		5	45	24.5

Category: 1= not important at all; 2= not important; 3= neither unimportant nor important; 4= important and 5= extremely important.

Furthermore, “Promotion of the food item. For example: being given free samples to try”, presented three significant ($p \leq 0.05$) correlations above r= 0.50. These three correlations were moderately positive correlations, namely: (i) “the trendiness of the food item” (r= 0.513); (ii) “the price of the new food item is cheaper when compared to other products” (r= 0.506) and lastly, (iii) “the use of the food item by friends and family (r= 0.509)” (Table 4.57).

Table 4.57: Spearman correlation analysis between the knowledge and awareness of new food products and trends, and the importance of the promotion of a food item (p ≤ 0.05).

Correlation:	The trendiness of the food item.	The price of the new food item is cheaper when compared to other products.	The use of the food item by friends and family.
Promotion of the food item. For example: being given free samples to try.	0.513	0.506	0.509

VII. Importance of the use of the food item by friends and family

The results for the statement, "The use of the food item by friends and family.", were presented in Table 4.58 as follows: a few (13.2%) (category 1+2) of the respondents did not consider this statement important; almost a quarter (24.7%) found it neither unimportant nor important, while most (62.1%) (category 3+4) of respondents considered it important. The overall mode was 4, indicating that most of the respondents considered the use of a new food item by friends and family an important consideration.

Table 4.58: Importance of the use of the food item by friends and family.

Question	Nr. of missing values	Category	n=182	%
The use of the food item by friends and family.	4	1	8	4.4
		2	16	8.8
		3	45	24.7
		4	80	44.0
		5	33	18.1

Category: 1= not important at all; 2= not important; 3= neither unimportant nor important; 4= important and 5= extremely important.

The respondents considered most of the statements as important to extremely important considerations when introducing a new food item into their diets. However, some respondents found the trendiness, promotion and if a new food item is cheaper when compared to similar products, as neither unimportant nor important.

VIII. How frequently respondents experiment with unusual ingredients

When asked if they would experiment with unusual ingredients (Table 4.59), the respondents presented the following results: never (2.1%); rarely (15.8%); sometimes (46.2%); regularly (27.2%) and always (8.7). The mode was 3, indicating that respondents would sometimes use unusual ingredients.

Table 4.59: Frequency of respondents experimenting with unusual ingredients.

Question	Nr. of missing values	Category	n=184	%
Experiment with unusual ingredients in meals that you prepare.	2	1	4	2.1
		2	29	15.8
		3	85	46.2
		4	50	27.2
		5	16	8.7

Category: 1= never; 2= rarely; 3=sometimes; 4= regularly and 5= always.

Furthermore, when respondents were asked how often they experimented with unusual ingredients in meals that they prepare, five significant (p ≤ 0.05) correlations were identified that were above r= 0.50 (Table 4.60). Two of these correlations were strong positive correlations, namely: (i) “substitute conventional products with new or unfamiliar products in recipes” (r= 0.723) and (ii) “try out new recipes” (r= 0.672). The remaining three correlations were moderately positive correlations, namely: (i) “keep your eyes open for new food products to try” (r= 0.555); (ii) “try new food products in stores” (r= 0.535) and lastly, (iii) “try out new food trends” (r= 0.572).

Table 4.60: Spearman correlation analysis between the knowledge and awareness of new food products and trends, and the frequency of respondents experimenting with unusual ingredients (p ≤ 0.05).

Correlation:	Substituted conventional products with new or unfamiliar products in recipes.	Keep eyes open for new food products to try.	Try new food products in stores.	Try new recipes.	Try new food trends.
Experimented with unusual ingredients in meals that they prepare.	0.723	0.555	0.535	0.672	0.572

IX. Substituting conventional products with new or unfamiliar products in recipes

The results for the statement, “Substitute conventional products with new or unfamiliar products in recipes.”, were presented in Table 4.61 as follows: never (2.2%); rarely (22.3%); sometimes (38.0%); regularly (28.8%) and always (8.7%). The overall mode was 3, indicating that the respondents sometimes substituted new products in recipes.

Table 4.61: Frequency of respondents substituting conventional products with new or unfamiliar products in recipes.

Question	Nr. of missing values	Category	n=184	%
Substitute conventional products with new or unfamiliar products in recipes.	2	1	4	2.2
		2	41	22.3
		3	70	38.0
		4	53	28.8
		5	16	8.7

Category: 1= never; 2= rarely; 3=sometimes; 4= regularly and 5= always.

Moreover, when respondents were asked if they, "substituted conventional products with new or unfamiliar products in recipes'', six significant ($p \leq 0.05$) correlations were identified that were above r= 0.50 (Table 4.62). Five of these correlations were strong positive correlations, namely: (i) "experimented with unusual ingredients in meals that you prepare" (r= 0.723); (ii) "keep your eyes open for new food products to try" (r= 0.603); (iii) "try new food products in stores" (r= 0.640); (iv) "try out new recipes" (r= 0.685) and lastly, (v) "try out new food trends" (r= 0.604). One positive correlation was "get excited when stores introduce new food products for you to try", which yielded a correlation coefficient degree of r= 0.538.

Table 4.62: Spearman correlation analysis between the knowledge and awareness of new food products and trends, and the frequency of respondents substituting conventional products with new or unfamiliar products in recipes ($p \leq 0.05$).

Correlation	Keep eyes open for new food products to try.	Try new food products in stores.	Try new recipes.	Try new food trends.	Get excited when stores introduce new food products for you to try.
Substituted conventional products with new or unfamiliar products in recipes.	0.603	0.640	0.685	0.604	0.538

X. How often respondents keep their eyes open for new food products to try

For the statement, "Keep your eyes open for new food products to try.", the results presented the following (Table 4.63): never (1.1%); rarely (11.9%); sometimes

(28.6%); regularly (33.5%) and always (24.9%). The overall mode was 4, indicating that respondents regularly kept a look out for new food products.

Table 4.63: How often respondents keep their eyes open for new products to try.

Question	Nr. of missing values	Category	n=185	%
Keep your eyes open for new food products to try.	1	1	2	1.1
		2	22	11.9
		3	53	28.6
		4	62	33.5
		5	46	24.9

Category: 1= never; 2= rarely; 3=sometimes; 4= regularly and 5= always

Furthermore, five significant ($p \leq 0.05$) correlations above r= 0.50 were identified for the statement, "keep eyes open for new food products to try" (Table 4.64). Three of these correlations were strong positive correlations, namely: (i) "substituted conventional products with new or unfamiliar products in recipes" (r= 0.603); (ii) "try new food trends" (r= 0.643) and (iii) "get excited when stores introduce new food products for you to try" (r= 0.742). One correlation was a very strong positive correlation: "try new products in stores" (r= 0.813); additionally, one moderate positive correlation was presented, namely: "try out new recipes" (r= 0.548).

Table 4.64: Spearman correlation analysis between the knowledge and awareness of new food products and trends, and how often respondents keep their eyes open for new food products to try ($p \leq 0.05$).

Correlation:	Substituted conventional products with new or unfamiliar products in recipes.	Try new food products in stores.	Try new recipes.	Try new food trends.	Get excited when stores introduce new food products for you to try.
Keep eyes open for new food products to try.	0.603	0.813	0.548	0.643	0.742

XI. How often respondents try new food products in stores

According to Table 4.65, respondents were asked how often they would try new food products in stores and the table presented the following results: never (0.5%); rarely (7.6%); sometimes (35.1%); regularly (37.8%) and always (19.0%). The overall mode was 4, indicating most respondents regularly tried new food products in stores. According to Nazzaro et al. (2019), brand loyalty is synonymous with quality. Therefore, increasing consumers' willingness to try new products in stores would be even more so, if those products would be introduced by a brand they valued.

Table 4.65: Frequency of respondents trying new food products in stores.

Question	Nr. of missing values	Category	n=185	%
Try new food products in stores.	1	1	1	0.5
		2	14	7.6
		3	65	35.1
		4	70	37.8
		5	35	19.0

Category: 1= never; 2= rarely; 3=sometimes; 4= regularly and 5= always.

Furthermore, for the statement, “try new food products in stores”, six significant ($p \leq 0.05$) correlations above r= 0.50 were identified (Table 4.66). Three of the correlations were strong positive correlations: (i) “substituted conventional products with new or unfamiliar products in recipes” (r= 0.640); (ii) “try out new food trends” (r= 0.698) and (iii) “get excited when stores introduce new food products for you to try” (r= 0.795). Two were moderately positive correlations: (i) “experiment with unusual ingredients in meals that you prepare” (r= 0.535) and (ii) “try out new recipes” (r= 0.545). One of the correlations was a very strong positive correlation, namely “keep eyes open for new food products to try” (r= 0.813).

Table 4.66: Spearman correlation analysis between the knowledge and awareness of new food products and trends, and the frequency of respondents trying new food products in stores. ($p \leq 0.05$).

Correlation:	Experiment with unusual ingredients in meals that you prepare.	Substituted conventional products with new or unfamiliar products in recipes.	Keep eyes open for new food products to try.	Try new recipes.	Try new food trends.	Get excited when stores introduce new food products for you to try.
Try new food products in stores.	0.535	0.640	0.813	0.545	0.698	0.795

XII. How often respondents tried out new recipes

When asked if they would try out new recipes, the respondents exhibited the following results (Table 4.67): never (0.5%); rarely (5.4%); sometimes (35.9%); regularly (33.2%) and always (25.0%). The overall mode was 3, indicating that respondents sometimes tried out new recipes.

Table 4.67: Frequency of respondents trying out new recipes.

Question	Nr. of missing values	Category	n=184	%
Try out new recipes.	2	1	1	0.5
		2	10	5.4
		3	66	35.9
		4	61	33.2
		5	46	25.0

Category: 1= never; 2= rarely; 3=sometimes; 4= regularly and 5= always.

The statement, "try out new recipes", presented five significant ($p \leq 0.05$) correlations above r= 0.50. Three of these correlations were strong positive correlations: (i) "experiment with unusual ingredients in meals that you prepare" (r= 0.672); (ii) "substituted conventional products with new or unfamiliar products in recipes" (r= 0.685) and (iii) "try out new food trends" (r= 0.708). Two were moderately positive correlations: (i) "keep your eyes open for new food products to try" (r= 0.548) and (ii) "try new food products in stores" (r= 0.545).

Table 4.68: Spearman correlation analysis between the knowledge and awareness of new food products and trends, the frequency of respondents trying out new recipes ($p \leq 0.05$).

Correlation:	Experiment with unusual ingredients in meals that you prepare.	Substituted conventional products with new or unfamiliar products in recipes.	Keep your eyes open for new food products to try.	Try new food products in stores.	Try new food trends.
Try new recipes.	0.672	0.685	0.548	0.545	0.708

XIII. How often respondents try out new food trends

For the statement, "Try out new food trends.", the following results were presented (Table 4.69): never (0.0%); rarely (11.4%); sometimes (35.3%); regularly (31.5%) and always (21.8%). The overall mode was 3, indicating that most respondents sometimes tried out new food trends.

Table 4.69: Frequency of respondents trying out new food trends.

Question	Nr. of missing values	Category	n=184	%
Try out new food trends.	2	1	0	0
		2	21	11.4
		3	65	35.3
		4	58	31.5
		5	40	21.8

Category: 1= never; 2= rarely; 3=sometimes; 4= regularly and 5= always.

For the statement, “try out new food trends'', six significant ($p \leq 0.05$) correlations above r= 0.50 were presented (Table 4.70). Five of the correlations were strong positive correlations, namely: (i) “substituted conventional products with new or unfamiliar products in recipes” (r= 0.604); (ii) “keep eyes open for new food products to try” (r= 0.643); (iii) “try new food products in stores” (r= 0.698); (iv) “try new recipes” (r= 0.708); (v) and “get excited when stores introduce new food products for you to try” (r= 0.666). A moderately positive correlation was presented for, “experiment with unusual ingredients in meals that you prepare” (r= 0.572).

Table 4.70: Spearman correlation analysis between the knowledge and awareness of new food products and trends, and the frequency of respondents trying out new food trends ($p \leq 0.05$).

Correlation:	Experiment with unusual ingredients in meals that you prepare.	Substituted conventional products with new or unfamiliar products in recipes.	Keep eyes open for new food products to try.	Try new food products in stores.	Try new recipes.	Get excited when stores introduce new food products for you to try.
Try out new food trends.	0.572	0.604	0.643	0.698	0.708	0.666

XIV. How often respondents get excited when stores introduce new food products

Table 4.71 presented the following results for the statement, “Get excited when stores introduce new food products for you to try'': never (0.0%); rarely (12.5%); sometimes (27.7%); regularly (28.3%) and always (31.5%). The overall mode was 5, indicating that most respondents were always excited when a store introduced new food products.

Table 4.71: Frequency of respondents getting excited when stores introduce new food products for them to try.

Question	Nr. of missing values	Category	n=184	%
Get excited when stores introduce new food products for you to try.	2	1	0	0
		2	23	12.5
		3	51	27.7
		4	52	28.3
		5	58	31.5

Category: 1= never; 2= rarely; 3=sometimes; 4= regularly and 5= always.

For the last statement, “get excited when stores introduce new food products for you to try”, four significant ($p \leq 0.05$) correlations above r= 0.50 were identified (Table 4.72). Three of these correlations were strong positive correlations: (i) “keep your eyes open for new food products to try” (r= 0.742); (ii) “try new food products in stores” (r= 0.795) and (iii) “try new food trends” (r= 0.666). A moderate positive correlation was presented for ‘’substituted conventional products with new or unfamiliar products in recipes” (r= 0.538).

Table 4.72: Spearman correlation analysis between the knowledge and awareness of new food products and trends, and the frequency of respondents getting excited when stores introduce new food products for them to try. (p ≤ 0.05).

Correlation:	Substituted conventional products with new or unfamiliar products in recipes.	Keep eyes open for new food products to try.	Try new food products in stores.	Try new food trends.
Get excited when stores introduce new food products for you to try.	0.538	0.742	0.795	0.666

In summary, the majority of respondents claimed to have sometimes consumed new ingredients and foods, as well as tried new recipes and food trends. According to Table 4.65 to 4.72, respondents regularly and always kept a look out for new food products available in stores, tried new products, new recipes and new trends, and got excited when new food products were introduced in stores for them to try.

4.6 CONCLUSION

In this chapter, consumers' attitudes and awareness were explored, analysed and discussed. The general picture that emerges for each construct presented the following findings:

4.6.1 Demographics:

As described in the sampling, students and staff completed the questionnaire at the UFS Bloemfontein campus. As a result, the respondents' demographic profile was representative of the study's location. Most of the respondents were under the age of 25 and grew up in the Free State Province. Since students and staff completed the questionnaire, the data showed that most respondents had received formal schooling. Due to the UFS's history as an Afrikaans-speaking university, most respondents spoke Afrikaans as a home language.

4.6.2 Acceptability of the product tasted:

Respondents in the study responded positively to the sensory characteristics of the product that was tasted. Three out of the four attributes (appearance, aroma, taste and texture) scored a neutral or ''like'' response, except for taste, on which most of the respondents remained neutral. Given the findings in Table 4.6, respondents agreed that they would consume, purchase and prepare the tasted product for friends and family.

4.6.3 Knowledge and awareness of the safety of maize:

The purpose of this section was to explore the respondent's understanding and knowledge about the safety of maize, and whether they were aware of processes that could improve the safety of maize, for safer consumption over long periods. Most respondents agreed that they were aware of other varieties of maize and were interested in learning about processes that would make maize safer to eat.

4.6.4 Consumer awareness of maize as a food source:

The aim of this section was to explore the respondent's awareness of the different colours of maize and which factors would influence respondents to consume them in the future. Most respondents had never seen, prepared or eaten maize of other colours/varieties, other than white and yellow maize. Additionally, according to Table 4.10, the respondents indicated that the health benefits, usage by peers, accessibility and affordability were the most important factors that would influence their willingness to consume nixtamalized maize in the future.

4.6.5 Knowledge and awareness of new food products and trends:

Respondents were asked which factors were important considerations to them when considering introducing a new food item into their diet. The health benefits, general availability, price of the new product, promotions and use by peers were rated as important considerations to the respondents. Respondents remained neutral on the trendiness of a new food item, with the majority rating it neither unimportant nor important. In Table 4.11, respondents were asked how often they would introduce a new food item, or ingredient or try out new recipes; most respondents claimed that they would sometimes do that. However, respondents claimed that they regularly kept a look out for new products to try and would always get excited when stores introduced new food products in stores.

As a final observation, the sensory appeal of a product could directly influence the likelihood of future consumption and purchasing. Furthermore, respondents deemed the safety of maize an important factor and were interested in a process that could be applied, to improve its safety. The respondents also reacted positively to new food products being introduced to the market, as long as those products were nutritionally beneficial, within their reach, and relatively affordable, compared to similar products.

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CHAPTER 5: NUTRIENT CONTENT OF A NOVEL NIXTAMALIZED MAIZE CHIP

5.1 INTRODUCTION

Maize, also known as corn, originates from the Americas and is believed to be over 80 000 years old, as fossilised maize pollen grains were found near Mexico City (Brown, 2018). It is estimated that South Africa, together with Nigeria, Ethiopia, Tanzania, Malawi, Kenya, Zambia, Uganda, Ghana, Mozambique, Cameroon, Mali, Burkina Faso, Benin, Democratic Republic of the Congo (DRC), Angola, Zimbabwe, Togo and Cote d'Ivoire, contributes to 96% of the total maize production in Sub-Saharan Africa (Macauley and Ramadjita, 2015). Despite being South Africa's second largest crop grown, maize is considered the most important cereal, because it forms part of a primary staple food amongst South African consumers (DAFF, 2020). In addition to its importance in South Africa, maize also plays a significant role in many other regions, such as Mexico, where the crop also serves as a staple (Ureta *et al*., 2020). Additionally, maize is a vital ingredient at household and industry levels as over 600 products are made of maize, with approximately half of these products consisting of nixtamalized maize (Ranum, Peña-Rosas and Garcia-Casal, 2014).

Nixtamalized maize is maize kernels that have been processed through nixtamalization, which is the processing technique that involves cooking maize kernels in an alkaline solution, typically calcium hydroxide. After cooking, the kernels are left to soak in the solution for a specified period, whereafter it is thoroughly washed and processed into different food products, such as tortillas, tamales and snack foods in a country such as Mexico (Alberdi-Cedeño *et al*., 2020). The process is beneficial in that it significantly reduces mycotoxins present in the kernel (Schaarschmidt and Fauhl-Hassek, 2019). Additionally, it further avails bound nutrients, such as vitamin B_3, lysine and tryptophan (Ranum, Peña-Rosas and Garcia-Casal, 2014). Sefa-Dedeh *et al.* (2004) further note that nixtamalization improves the calcium and protein quality in maize.

As mentioned previously, maize is a primary staple food, which also serves as a vital ingredient in many different food items, including maize meal, breakfast cereal and snacks, such as maize chips (Sydenham *et al.*, 1991). According to Brown (2018), maize is processed into various other products that play significant roles in many food applications. Some of these products include corn flour, corn syrup and corn oil. The production of corn flour consists of finely ground maize endosperm, and is used to thicken gravies, sauces and desserts. On the other hand, corn syrup is a viscous liquid consisting of fructose, glucose, maltose and dextrins, which is used to increase the sweetness in many food products. In addition, oil is extracted from the germ of the maize kernel and is used in many cooking applications, such as household food preparation (Brown, 2018).

Research shows that consumers are becoming increasingly aware of healthier snack options, with a higher nutritional value (Agrahar-Murugkar, Zaidi and Dwivedi, 2018). According to Costa *et al.* (2010), snacking forms part of consumers' daily eating and drinking habits, and it is, thus, important for snacks to be available on shelves, to fulfil the demands of the health-conscious consumer. This group of consumers no longer snack for enjoyment, but rather to increase their intake of essential nutrients (Norazmir *et al*., 2014). Nuss and Tanumihardjo (2011) highlight that snacks produced from white maize are the most consumed; however, they are deficient in the essential amino acids, lysine and tryptophan. Furthermore, the heavy dependency on starchy foods, as well as a diet low in a diversity of nutrient-rich foods, significantly contribute to malnutrition in developing African countries, more so in sub-Saharan Africa (Beswa *et al.*, 2016).

With the intention to deliver a snack with nutritional benefits, a novel nixtamalized maize chip was developed in the Consumer Science Food Laboratory at the Department of Sustainable Food Systems and Development, University of the Free State (UFS), Bloemfontein, Free State Province (FSP) South Africa (RSA). The chip was formulated using nixtamalized maize flour, cake flour, salt, water and oil. The method of cooking involved deep-frying the chip at 180 °C for 20 seconds on each side, until golden brown. By using the Just-About-Right (JAR) scale in the Sensory Laboratory at the Department of Sustainable Food Systems and Development, the chip was evaluated sensorily and gained acceptance by 75.0% of consumers. Prior to sensory analysis, ethical clearance (UFS-HSD2021/0668) was obtained from the General/Human Research Ethics Committee (GHREC) at the UFS on the 2nd of August 2021 (Appendix A).

The aim of this chapter was to determine the nutrient content of the newly developed nixtamalized maize chip through nutritional analysis, as well as comparing it to the nutritional status of existing products.

5.2 MATERIALS AND METHODS

5.2.1 Sample preparation

The maize chip gained consumer acceptance prior to nutritional analysis being carried out, using the JAR scale. The JAR scale is a bipolar assessment with two opposite reference points labelled "too little" and "too much," while the midpoint is labelled "just about right," indicating the respondents' ideal acceptance level (Li, Hayes and Ziegler, 2014). According to *Chapter 3: Consumer Acceptability of Novel Nixtamalized Maize Products*, the third JAR task for the nixtamalized maize chip represented the following results, for each of the attributes: appearance (73.0%); aroma (71.0%); taste (79.0%); and mouthfeel (75.0%). These percentages indicated that the chip gained consumer acceptance. Meullenet, Xiong and Findlay (2008) noted that a product, with a JAR rating of 70.0% or higher, for all attributes, could be considered “just about right”.

For the purpose of this analysis, three batches of maize chips were independently prepared as samples 1, 2 and 3. The preparation of the samples was completed in the Department of Sustainable Food Systems and Development on the 1st and 2nd of August 2022. Each sample was formulated and processed according to the standardised formula and procedure outlined in Chapter 3, Table 3.28. The formulation used for the maize chips included all-purpose flour, nixtamalized white masa flour, salt, olive oil, water and fruit chutney seasoning (NJ1024P) from Nicola-J Flavours & Fragrances, 64 Capital Hill Commercial Estate, Le Roux Avenue, Midrand, 1683. After mixing the ingredients together, the resulting outcome was a flexible dough. The dough was then thinly rolled on a floured surface with a rolling pin and cut into circular shapes, measuring 4 cm in diameter. These circular shaped chips, were then deep-fried in sunflower oil, which had been heated to a temperature of 180 °C. Following frying, the chips were placed on sheets of paper towel, to remove any excess oil. Once the frying process was complete, the chips were placed close together on a cooling rack and dusted with fruit chutney seasoning using a tea sieve. After seasoning, the chips were packaged in airtight plastic bags. Thereafter, the chips were nutritionally analysed on the 2nd of August 2022 at the Department of Animal Sciences, UFS, Bloemfontein, FSP. The maize chips were compared to two popular commercialised maize chips: Doritos; and Fritos, both manufactured by Simba (Pty) Ltd at Andre Greyvenstein Avenue, Isando, 1600. The nutritional information of the chips was accessed on the Simba website.

5.2.2 Nutritional analysis

I. Gross energy

Food stores energy as chemical energy in its chemical components, which can be converted into usable energy when consumed. The determination of the energy content of food entails the conversion of its chemical energy into heat energy through combustion, quantifying the subsequent heat that is generated. Thus, gross energy represents the absolute amount of heat generated, when a unit mass of food is completely oxidised (McDonald *et al*., 2010). The quantity of the heat produced was subsequently calculated from the weight of the food sample oxidised, the weight of the water, the increase in the temperature of the water, and the specific heat capacities of both the water and the bomb (McDonald *et al*., 2010). The gross energy of food is expressed as megajoules (MJ). Gross energy is used to quantify the nutritional intake of energy from food.

The methodology employed for obtaining the gross energy values of the chip was in accordance with the procedure outlined by McDonald *et al*. (2010). The method used a specialised device, known as the bomb calorimeter. This apparatus is composed of a sturdy container that is positioned within an insulated container, filled with water. The food sample was pelleted and placed in the bomb, which was then pressurised to 25 atmospheres, with oxygen. The initial temperature of the water in the bucket was recorded before the sample was electrically ignited. Upon combustion of the sample in an oxygen-rich environment, heat was generated and dissipated through the walls of the bomb, causing the temperature of the water in the container to increase. Once a state of equilibrium was achieved, the final temperature of the water was recorded. It is important to note that, gross energy was prioritised over carbohydrate content, due to the absence of carbohydrates listed on the nutrition label of the commercial chips used as a comparative reference.

II. Crude Protein

For protein determination, the Dumas and Kjeldahl methods are commonly used, however, Mihaljev *et al*. (2015) reported that that the Dumas method has a higher precision rate than the Kjeldahl method. Therefore, the Dumas method of combustion (ASM 056) (AOAC, 2005), with a LECO FP 2000 machine, was utilised to determine crude protein, as outlined by Zietsman (2008). The analysis was carried out by weighing 1 g of oven-dried sample and placing it directly into a reusable boat, which was then placed into a purge chamber, of a horizontal furnace. The sample was combusted in the presence of oxygen at a temperature of 950°C, resulting in the production of gases. The gaseous products were passed through a thermo-electric cooler, to eliminate most of the moisture and the gases were collected in a ballast chamber. Nitrogen was measured, using a thermal conductivity detector against a background of pure helium. The detector signal was transmitted to a computer via a microprocessor and the data was analysed, to determine the nitrogen content of the sample. The crude protein of the chips (g/100g DM) was calculated by multiplying the nitrogen content (g/100g DM), with a factor of 6.25 (Hauck, 1982; Kirsten,1983).

III. Fibre

The acid-detergent fibre (ADF) method (ASM 059) was used to determine the fibre content present in the chips (Robertson and Van Soest, 1981; AOAC, 2005). It involves dissolving 20 g N-cetyl-N,N,N-trimethyl ammonium bromide ($C_{19}H_{42}BrN$) in 1 litre (L) 1 N sulphuric acid (28 ml 98% sulphuric acid filled up to 1 L with distilled water) in glass pill vials. The mixture was dried in an oven overnight at 100°C. Once the 24 hours (h) had lapsed, the sample was placed in a desiccator for 30 minutes (min) to reach room temperature, then placed in a hot extraction unit and cooled on cooling water in the condenser. One hundred millilitres of acid detergent solution (ADS) were added to the samples and then heated on an element for 60 min. The samples were filtered and washed three times with hot distilled water and rinsed twice with acetone. Thereafter, the samples were oven dried at 100°C overnight and cooled in the desiccator for 30 min. Afterwards, the samples were placed in a muffle furnace at 550°C for 4 h and then cooled for 30 min. The remaining ash was used to determine the fibre content (Robertson and Van Soest, 1981).

The neural detergen fibre (NDF) was determined by the procedure outline by Van Soest, Robertson and Lewis (1991). The sample preparation and analysis involved multiple steps, including oven drying at 55°C until the dry matter content exceeded 85% and grinding, followed by drying and hot weighing of 50 ml glass crucibles. Approximately 0.5 g of the sample was placed in a 600 ml Berzelius beaker. In a digestion burette, approximately 45 ml of NDF solution was added, and the heating process began. The sample was mixed and then weighed into a plastic weigh pan. After gentle boiling, the sample was poured into the burette, and refluxing continued for 60 minutes. Afterward, 2 ml of amylase solution were added, and the burette's sides were rinsed. Glass crucibles were hot weighed before filtration, and the samples were filtered using vacuum. Acetone was added, and the samples were rinsed before being placed in a 105°C oven overnight. The samples were weighed with crucibles the following day.

IV. Analysis of the total extractable fat content

Total lipids from the maize chips were quantitatively extracted, according to the method of Folch *et al*. (1957), using chloroform and methanol in a ratio of 2:1. An antioxidant, butylated hydroxytoluene, was added at a concentration of 0.001% to the methanol chloroform-methanol mixture. A rotary evaporator was used to dry the fat extracts under vacuum and the extracts were dried overnight, in a vacuum oven at 50°C, using phosphorus pentoxide as a moisture adsorbent. Total extractable fat was determined gravimetrically from the extracted fat and expressed as percentage fat (w/w) per 100g maize chips. The fat-free dry matter (FFDM) content was determined by weighing the residue on a pre-weighed filter paper, used for Folch extraction, after drying. By determining the difference in weight, the FFDM could be expressed as % FFDM (w/w) per 100g sample. The moisture content of the maize chips was determined by subtraction (100% - %lipid - %FFDM) and expressed as percentage moisture (w/w) per 100g tissue.

The extracted fat from the maize chips was stored in a polytop (glass vial, with push-in top), under a blanket of nitrogen and frozen at –20°C, pending the fatty acid analyses.

V. Analysis of fatty acids

A lipid aliquot (25 mg) was transferred into a Teflon-lined screw-top test tube, by means of a disposable glass Pasteur pipette. Fatty acids (FAs) were trans-esterified to form methyl esters, using 0.5 N sodium hydroxide in methanol and 14% boron trifluoride in methanol (Park and Goins, 1994). Analysis was performed, using an initial isothermic period (40°C for 2 min). After that, the temperature was increased at a rate of 4°C/min to 230°C. Finally, an isothermic period of 230°C for 10 min followed. Fatty acid methyl ester (FAME) n-hexane (1μl) was injected into the column, using a Varian CP 8400 Autosampler. The injection port and detector were both maintained at 250°C. Hydrogen, at 45 pounds per square inch (psi), functioned as the carrier gas, while nitrogen was employed as the makeup gas. Galaxy Chromatography Software recorded the chromatograms.

Fatty acid methyl ester samples were identified, by comparing the retention times of FAME peaks from samples, with those of standards obtained from Supelco (Supelco 37 Component Fame Mix 47885-U, Sigma-Aldrich Aston Manor, Pretoria, South Africa). All other reagents and solvents were of analytical grade and obtained from Merck Chemicals (Pty Ltd, Halfway House, Johannesburg, South Africa). Fatty acids were expressed as the proportion of each individual FA to the total of all FAs present in the sample. The saturated fatty acid (SFA) percentage of the two commercialised chips were calculated as follows:

$$SFA\% = \frac{SFA\ (g)}{totalfat(g)} x100$$

The following FA combinations were calculated: omega-3 (n-3) FAs, omega-6 (n-6) FAs, total SFAs, total monounsaturated fatty acids (MUFAs), polyunsaturated fatty acids (PUFAs), PUFA/SFA ratio (P/S) and n-6/n-3 ratio.

VI. Minerals

A spectroscopic analysis of the chips' mineral content was conducted, using atomic absorption flame spectroscopy for calcium and magnesium (Valderrama-Bravo *et al*., 2010; AOAC, 1990; GBC, 1991; Price, 1972), and flame emission spectroscopy for sodium and potassium (Vlab.amrita.edu, 2012; Poluektov, 1973). Firstly, the calcium and magnesium content of the maize chips samples were determined by the dry ashing AOAC method 927.02. The quantity of remaining calcium and magnesium was analysed, using a double-beam atomic absorption spectrometer, specifically the Analyst 300 Perkin Elmer model. A calcium standard, with a concentration of 1000 parts per million (ppm), was used to generate a calibration curve. The spectrometer was operated with 12 psi of dry air and 70 psi of acetylene, using a 422.7 nanometer (nm) flame, a 10 milliampere (mA) lamp current, and a 0.7 nm slit width. The average of the calcium and magnesium contents was recorded for each sample. Secondly, flame emission spectroscopy for sodium and potassium was conducted by preparing standard solutions of sodium and potassium, using their respective salts. These solutions were then aspirated into a flame, where they were atomised and excited by the heat of the flame. The excited atoms emitted characteristic wavelengths of light, which were measured by a detector and converted into a signal. The intensity of the signal was proportional to the concentration of the element in the sample. Calibration curves were constructed using standard solutions of known concentrations, and the concentration of sodium and potassium in the sample was determined, by comparison to the calibration curves. The intensity of the light, emitted by the flame, was measured and used to determine the concentrations of sodium and potassium in the sample. Lastly, phosphorus was examined using the AOAC method 931.01 (AOAC, 1997). This involved burning 1 gram samples in porcelain crucibles for 6 hours at 500°C in a Carbolite C.E. furnace, and then dissolving the ash in 100 ml volumetric flasks with distilled, deionised water and a small amount of concentrated hydrochloric acid. The amount of phosphorus present in the solution was determined by utilising colorimetric measurements with the aid of a Spectronic 20 instrument (Milton Roy Co., UK).

5.3 RESULTS AND DISCUSSION

5.3.1 Nutrient content of the maize chip compared to other maize snacks

The following section outlines the quantitative results obtained through triplicate analysis of the nixtamalized maize chips, as shown in Table 5.1. Additionally, Table 5.2 aims to gain insight and knowledge on the nutrient content of the nixtamalized maize chips compared to commercial maize chip brands. The nutrient content of commercial chips was sourced from an online database and is utilised for the purpose of comparing the nutrient content of the maize chip with other well-known maize chip brands. Furthermore, Figure 5.1 presents a photograph of the newly developed maize chip as well as the two popular commercialised maize chips.

Nixtamalized maize chips
Source: (Researcher, 2022)

Doritos sweet chilli corn (maize) chips
Source: (Simba, 2019a).

Fritos barbeque corn (maize) chips
Source: (Simba, 2019b).

Figure 5.1: Newly developed maize chip and two commercial maize chips.

Table 5.1: Nutrient content of the nixtamalized maize chip per 100g (n=3).

Nutrient	Nixtamalized maize chips Sample 1 per 100g	Nixtamalized maize chips Sample 2 per 100g	Nixtamalized maize chips Sample 3 per 100g	Nixtamalized maize chip mean value per 100g
Energy (kJ/100 g)	2316	2309	2285	2303
Protein (g/100 g)	6.77	6.67	6.49	6.64
NDF (g/100 g)	15.98	17.31	14.33	15.87
ADF (g/100 g)	1.27	1.33	1.37	1.32
Fat (g/100 g)	23.48	23.96	23.72	23.72
Saturated fat (g/100 g)	11.38	11.57	11.48	11.47
Calcium (mg/100g)	167	166	157	163.33
Magnesium (mg/100 g)	55	55	51	53.67
Sodium (mg/100 g)	752	673	695	706.67
Potassium (mg/100 g)	159	155	149	154.33
Phosphorus (mg/100 g)	566	566	566	566

No significant differences were determined between values.

Table 5.2: Comparison of the nutrient content of the nixtamalized maize chip and two commercial chips, Doritos sweet chilli and Fritos barbeque, per 100g.

Nutrient	Maize Chips	Doritos	Fritos
Energy (kJ/100 g)	2303	1944	2142
Protein (g/100 g)	6.64	6.70	6.20
Fat (g/100 g)	23.72	20.70	31.00
Saturated fat (g/100 g)	11.47	8.3	12.2
Sodium (mg/100 g)	706.67	634.00	685.00

I. Gross energy

In Table 5.1, the average energy content of the nixtamalized maize chips was 2303 kJ/100g. The gross energy content of the three repetitions were 2316 kJ/100 g, 2309 kJ/100 g and 2285 kJ/100 g, respectively. The first repetition had higher kJ content per 100 g. Furthermore, the energy content of the Doritos (1944 kJ/100g) and Fritos (2142 kJ/100g) proved to be lower than the maize chips (Table 5.2). Despite the differences between the maize chips and the commercial chips, all three products exhibit a high energy content, since food items containing 170 kJ/100 g or less are considered to have a low energy content (Van Heerden, 2011). However, the high energy content of the nixtamalized maize chip could be attributed to the dry heat cooking method of deep-frying, where oil absorption in the fried product takes place (Ouchon, Aguilera and Pyle, 2003). During deep frying, a food product is submerged in hot oil, with temperatures ranging from 120 °C to 180 °C. The heat from the hot oil is transferred to the inside of the product, while the internal moisture (water) is released as steam. This provides rapid heat transfer and shorter cooking times (Dana and Saguy, 2006). Additionally, deep-frying yields distinctive sensorial characteristics, associated with fried foods, such as the change of colour, development of a crust and gelatinisation (Yildiz, Palazoğlu and Erdoğdu, 2007). It is important to highlight that the release of steam during frying results in the development of a porous surface, which improves the crispy and crunchy texture of deep-fried potato chips (Yang *et al*., 2017; Ziaiifar, Courtois and Trystram, 2010). However, the porous surface on a deep-fried food's surface increases its capacity to absorb oil during and after frying, consequently resulting in increased oil absorption (Brown, 2018). Therefore, deep-fried foods are high in fat and offer a higher energy (kJ) content, as opposed to non-fried food products (Asokapandian, Swamy and Hajjul, 2020). Moreover, it is important to note that gross energy only reflects the theoretical maximum level of energy, not the energy consumed by humans. Thus, some energy may be lost during digestion, as not all foods are fully absorbed by the digestive system (WHO/FAO, 2002).

II. Crude protein content

Protein is a macronutrient that plays a vital role in building cells and body tissues. Proteins are made of 22 amino acids (AAs); however, the human body does not synthesise essential AAs and, thus, must be acquired through food (Brazier, 2020). Proteins are further categorised into complete and incomplete proteins. Complete proteins are usually from animal sources and contain all the essential AAs, while incomplete proteins come mainly from plants and do not provide all the essential AAs (Brown, 2019). Additionally, there is evidence linking protein-rich snacks to extended periods of satiety, as demonstrated by Marmonier, Chapelot and Louis-Sylvestre (2000). Their study examined the impact of nutrient content in an afternoon snack on the timing of the subsequent meal. The study included a group of young men who consumed either a high-fat, or a high-protein, or a high-carbohydrate snack 4 hours after lunch. Results showed that the high-protein snack produced the most significant feeling of satiety, followed by the high-carbohydrate snack and the high-fat snack. This indicated that the participants who ate the high-protein snack remained fuller for longer, before requesting dinner. These findings support the concept that high-protein snacks promote greater satiety, compared to snacks high in other nutrients. The feeling of satiety, characterised by a prolonged feeling of fullness following a meal, plays a vital role in reducing overconsumption, which may lead to weight gain and obesity (Benelam, 2009). However, according to Jiang, Hettiararchchy, and Horax (2019), maize chips are widely recognised for having a low protein content such as the low protein present in the maize chips (6.64 g/100 g) (Table 5.1). Furthermore, Table 5.2 indicates that the nixtamalized maize chips fell within the same range as the Doritos (6.7 g/100g) and Fritos (6.2 g/100 g). It could thus be concluded that the protein content in the nixtamalized maize chips is comparable to the two commercial chips.

III. Neutral detergent fibre (NDF) and acid-detergent fibre (ADF)

The ability of fibres to dissolve in water distinguishes them into soluble and insoluble fibres. According to Brown (2018), soluble fibres dissolve in water, whereas insoluble fibres do not. Neutral-detergent fibre and acid-detergent fibre are both insoluble fibres that act as sponges in the intestine, by soaking up water. Consequently, the softness and bulkiness of the stool are increased, thereby decreasing the risk of constipation and promoting bowel health (Brown, 2018). Neutral-detergent fibre forms part of the structural components of plants, specifically the cell wall, whereas acid-detergent fibre comprises of the least digestible plant components, such as cellulose and lignin (Sonon *et al*., 2023). Insoluble fibres assist in reducing the risk of constipation and colon cancer (Brown, 2018; Whitney and Rolfes, 2018). According to Nuss and Tanumihardjo (2010), common maize varieties contain about 12% of insoluble fibre, with processed corn having a reduced amount. Naggayi *et al.* (2020) note that nixtamalized maize commonly has a 10 to 12% decrease in insoluble fibres, due to the removal of the pericarp. Table 5.1 shows that the NDF content in the nixtamalized maize chips was higher than the ADF content, with 15.87 g/100 g NDF and 1.32 g/100 g ADF, respectively. The insoluble fibre content in popcorn is 14 g/100g, which is lower than compared to the nixtamalized maize chip (USDA, 2022). The insoluble fibre content of the nixtamalized maize chips and popcorn differs slightly, with nixtamalized maize chips having a higher content.

IV. Mineral content

a) Calcium:

The calcium content of the nixtamalized maize chip was found to be slightly less than half the amount found in milk, measuring at 163.33 mg per 100 g (Table 5.1). Milk, known to be a significant source of calcium, typically contains an average of 300 mg of calcium per cup, as reported by Brown (2018). The calcium content in the two commercial chips were deemed inadequate for inclusion in the nutritional table, indicating that these products should not be relied upon as a viable source of dietary calcium. However, calcium is the most abundant mineral in the body, and is also present in some foods and commercially available as nutritional supplements (Amalraj and Pius, 2015). It is an essential mineral that the body uses to maintain and build strong bones, and plays an essential role in relaying messages between the brain and all the different body parts through nerves. Additionally, it helps blood vessels carry blood throughout the body and release hormones that have many different functions (National Institutes of Health, 2019). However, in regard to the nixtamalization of maize, Trejo-Gonzalez *et al*. (1982) notes that the use of calcium hydroxide increases the calcium content in nixtamalized products, due to the cooking and steeping time. Although milk and the nixtamalized maize chips are good sources of dietary calcium, other foods such as raw ripe bananas and cucumbers also contribute to calcium intake, although to a minor extent. For example, raw ripe bananas contain approximately 5 mg of calcium per 100 g (USDA, 2020), whereas a 100 g cucumber has a comparatively higher calcium content of 16 mg (USDA, 2022b).

b) Magnesium:

Magnesium is an invaluable mineral that the body needs to maintain overall health. It is instrumental in regulating muscle and nerve function, blood sugar levels, as well as blood pressure. Additionally, it manufactures and maintains protein, bones and DNA

(National Institutes of Health, 2016). The average magnesium content for the nixtamalized maize chips was very low, at 53.67 mg/100 g (Table 5.1). According to Kikunaga, Ishii and Takahashi (1995), nuts, unrefined cereals and seaweeds are the richest sources of magnesium. However, the consumption of these foods is minor, compared to green leafy vegetables, such as spinach, which are also high in magnesium and are more commonly consumed. Notably, the USDA (2021) enlists mature spinach as containing an average of 93 mg/100 g. Again, the magnesium content of the commercial chips was too low to be included in the nutritional table. Moreover, the USDA (2022b) reports that cucumber contains about 10.1 mg/100 g of magnesium, while dried apple chips contain 16 mg/100 g (USDA, 2022c), making these additional sources of this essential mineral.

c) Sodium:

Food industries use sodium extensively, because of its low cost and diverse properties. Due to sodium chloride's ability to reduce water activity values, it has both preservative and antimicrobial properties. Additionally, sodium chloride enhances flavours by reducing or enhancing the enzymatic activity of some enzymes, involved in the development of different organoleptic parameters, through its effects on different biochemical mechanisms (Albarracín *et al.*, 2011). Sodium chloride, commonly known as salt, is thus used as a flavour enhancer in food. However, high dietary salt intake is linked to elevated blood pressure, a major risk factor for cardiovascular disease (He, Li and MacGregor, 2013). In 2010, an estimated 1.65 million cardiovascular deaths worldwide were attributed to salt consumption above the World Health Organization's (WHO) recommended intake of 5 g per day (WHO, 2010; WHO, 2012). Furthermore, the WHO (2010) emphasised that reducing the salt content in foods is an optimal and cost-effective way to investment in reducing the impact of elevated blood pressure and cardiovascular diseases. According to Hofman and Lee (2013), South Africa has, thus, become the pioneer in developing mandatory legislation to reduce the salt content in processed foods, with the cooperation of the food industry. The sodium legislation was passed in 2013 by the South African Department of Health, which set out to enforce strict restrictions on the maximum levels of salt permitted in commonly consumed foods by South African consumers, such as bread, breakfast cereals, margarine, meat products, snack foods and soup mixes (Department of Health, 2017). Additionally, it should be noted that the South African government enforced that ‘’ready-to-eat savoury snacks" such as extruded, expanded or puffed snacks made from maize, potato, rice and other cereals should contain no more than 800 mg/100 g of salt (Government Gazette, 2017). This maximum level of sodium for snack foods became effective by 30 June 2016. Evidently, Table 5.1 and 5.2 indicates the sodium content present in the nixtamalized maize chips, Doritos and Fritos abide by this law as each product contains 706.67 mg, 634 mg and 685 mg per 100g, respectively.

d) Potassium:

The nixtamalized maize chips exhibited an average content of 154.33 mg per 100 g (Table 5.1). Dietary sources of potassium are abundant, with potatoes being the highest source, according to Weaver (2013). Specifically, the USDA (2022d) reported that peeled russet potatoes contain about 450 mg of potassium per 100 g. The two commercial chips, in the present study, again showed no values for potassium, indicating that the potassium contents were too low. Also cooked white rice contains approximately 35 mg/100 g of potassium (USDA, 2022e), which is also very low. Potassium is an indispensable mineral in the human diet, due to its involvement in several physiological processes. It plays a significant role in maintaining the acid-base balance, distributing water both inside and outside of cells, and facilitating nerve activity, by creating a membrane potential. Additionally, potassium actively participates in the metabolism of cells, including energy conversion, hormone secretion, protein synthesis and glycogen synthesis (Turck *et al*., 2016).

e) Phosphorus:

Phosphorus is a vital mineral in the human body, which is involved in many essential functions. Among these functions are the cell energy cycle, regulating the body's acid-base balance, as well as the mineralisation of bones and teeth. The bones and teeth contain 85% of the body's phosphorus, while soft tissues (muscles, heart, kidneys) contain 14%, and extracellular fluid contains the remaining 1% (Kalantar-Zadeh *et al*., 2010). The phosphorus content in the nixtamalized maize chips was measured at 566 mg/100 g, which is comparable to protein-rich foods like dairy, meat, and fish that are known to be primary sources of phosphorus (Kalantar-Zadeh *et al*., 2010). According to USDA (2019a), whole milk contains an average of 84 mg/100 g of phosphorus, while chicken contains 178 mg/100 g, indicating that the nixtamalized maize chips could be a valuable dietary source of phosphorus. In contrast, raw grapes contain only 22 mg/100 g of phosphorus (USDA, 2022e). It is worth noting that the nutritional tables for Doritos and Fritos do not disclose information about their phosphorus content, which may imply that these products may not contain significant amounts of phosphorus. Furthermore, the recommended daily allowance for phosphorus varies by age group, with 500 mg for ages 4-8, 1,250 mg for ages 9-18, and 700 mg for individuals 19 years and older (National Institute of Health, 2021).

5.3.2 Total lipid and fatty acid analysis

The lipid and fatty acid contents of the nixtamalized maize chip is shown in Table 5.3.

Table 5.3: Total lipid and fatty acid content of the nixtamalized maize chip

Total lipid and fatty acid analysis	Nixtamalized maize chips Sample 1 per 100g	Nixtamalized maize chips Sample 2 per 100g	Nixtamalized maize chips Sample 3 per 100g	Nixtamalized maize chip mean value per 100g
Proximate Analysis:				
% Fat	23.48	23.96	23.72	**23.7**
Fatty acid ratios:				
Saturated Fatty Acids (SFAs)	11.38	11.57	11.48	**11.47**
Monounsaturated Fatty Acids (MUFAs)	40.00	39.88	39.94	**39.93**
Polyunsaturated Fatty Acids (PUFAs)	48.63	48.55	48.59	**48.58**
Total Omega-6 Fatty Acids (n-6)	48.46	48.36	48.41	**48.41**
Omega-3 Fatty Acids (n-3)	0.16	0.19	0.18	**0.17**
PUFA:SFA	4.27	4.19	4.23	**4.23**
n-6/n-3	296.42	256.85	276.64	**276.63**

I. Total percentage fat

The nixtamalized maize chips had a total fat content of 23.72 g/100 g (Table 5.3), which was lower compared to Fritos (31.00 g/100 g) but higher than Doritos (20.70 g/100 g), as shown in Table 5.2. The high fat content in the nixtamalized maize chips was attributed to deep-frying the product in oil. One of the main concerns with deep-fried foods is problems associated with their high oil content, such as obesity, high levels of cholesterol or high blood pressure (Brannan and Pettit, 2015; Dourado *et al.,* 2019). Literature suggests mitigating viable strategies to reduce oil uptake in deep-fried foods. These strategies include modifying the surface of the food, by using a batter and breading, modifying the frying oil or technique, vacuum frying, microwave heating, de-oiling and air frying (Liberty, Dehghannya and Ngadi, 2019). They further state that the first mentioned strategy has been reported as the most effective, as oil uptake occurs mostly at the food surface, known as the crust. The coatings and breading inhibit oil absorption by forming a barrier against moisture loss, during frying. However, air frying could be the best method of reducing oil uptake, as Shaker (2015) reported that air frying is effective in reducing oil uptake in potato chips. However, animal fats and plant oils, present in foods, provide energy and essential FAs. High SFAs concentrations are found in animal sources, such as butter, which is associated with cholesterol. In contrast, plant oils have a higher concentration of UFAs, which are heart-healthy. Thus, the food industry has progressively moved away from animal fats to plant oils, due to consumers demanding food products that are nutritionally beneficial (Saoussem *et al.*, 2009).

II. Fatty acid ratio

a) Saturated fatty acid, monounsaturated fatty acid and polyunsaturated fatty acid ratio

Saturated fatty acids have been positively associated with cardiovascular diseases, as well as with high cholesterol levels. It has been proven that replacing or substituting SFAs with PUFAs and MUFAs has reduced the risk of CVD and health conditions, related to SFAs (Hammad, Pu and Jones, 2016). The total FA content is, thus, made up of SFAs, MUFAs and PUFAs. Figure 5.2 provides a visual representation of the ratio makeup of the FA content of the nixtamalized maize chips. According to Table 5.3, most of the total fats of the nixtamalized maize chips were PUFAs (49.0%), while 40.0% were MUFAs. The SFAs made up the least (11.0%) of the FAs present in the nixtamalized maize chips, which shows a big difference between MUFAs and PUFAs compared to SFAs. The SFA content of nixtamalized maize chips is considerably lower than that of the Doritos (8.3÷20.7x100= 40.1%) and Fritos (12.2÷31.0x100= 39.4%) (Table 5.2). MUFA and PUFA content in the Doritos and Fritos were not stipulated in the nutrition label of the commercialised chips. The PUFAs and MUFAs make up the majority of the FAs present in the nixtamalized maize chips, because olive and sunflower oil was used in the formulation of the nixtamalized maize chips, and these oils are the major sources of PUFAs and MUFAs (Brown, 2018).

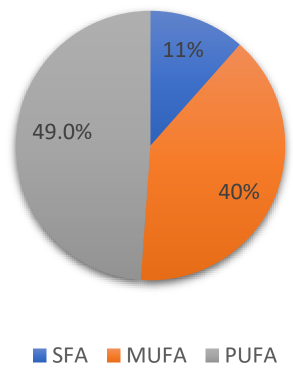

Figure 5.2: SFA, MUFA and PUFA ratios of the nixtamalized maize chip.

b) Omega-3 and Omega-6 ratio

Eicosapentaenoic acid (EPA) represents the omega-3 content while linoleic acid represents the omega-6 content. According to Table 5.3, the omega-3 content in the nixtamalized maize chips was limited to 0.17% per 100 g. Eicosapentaenoic acid is a polyunsaturated omega-3 FA, in which the first double bond is three carbons from the methyl (CH_3) end, which plays an important role in both human and animal health (Hamilton *et al.*, 2020; Brown, 2018). This fatty acid is most commonly found in seafood, such as salmon and herring, and its consumption has been positively linked to cardiovascular and inflammatory diseases, such as arthritis, as well as neurological conditions and diabetes (Gu, Kavanagh, and McClure, 2021). This is due to EPA being a precursor in eicosanoid synthesis, which is part of a class of signalling molecules, involved in cellular processes, such as inflammation (Calder, 2006).

According to Table 5.3, linoleic acid accounts for almost half (48.41% per 100 g) of the FAs present in the nixtamalised chips. Furthermore, Alberdi-Cedeño *et al.* (2020) reported that lipids, available in nixtamalized maize, are richer in linoleic than oleic groups. Linoleic acid (C18:2c9,12 (n-6)) is an essential omega-6 PUFA that cannot be synthesised by the body, requiring it to be consumed through the diet. This FA contains two double bonds at the ninth and 12th carbons from the carbonyl functional group. It is primarily found in vegetable oils, nuts, seeds, meats and eggs (Whelan and Fritsche, 2013). Polyunsaturated fatty acids play vital roles in many biological processes in the body, such as being endogenous mediators for cell signalling, as well as being involved in the regulation of gene expression (Choque *et al*., 2014).

The findings indicated that the omega-6 content was much higher than the omega-3 content, likely due to the use of sunflower oil in cooking, which contains 69.0% linoleic acid, as reported by Khan *et al.* (2015). Furthermore, the comparison between the FA content of high-oil maize hybrids and the analysed nixtamalized maize chips could identify any significant differences in content. Studies by Wang and White (2019), and Preciado-Ortíz *et al*. (2018) confirm that linoleic acid, together with oleic acid, are the primary FAs present in maize, accounting for over 98.0% of the FA content in high-oil maize hybrids.

5.4 CONCLUSION

Based on observations, it can be concluded that the cooking method of deep-frying is responsible for the high energy and fat content found in the nixtamalized maize chips. However, despite these drawbacks, deep-frying is critical in providing the chips with its distinctive flavour profile and crispy texture, which was highly valued by the consumer panel. It is, thus, challenging to attain the aforementioned sensory attributes using alternative cooking methods, such as air frying, as deep-frying also enhances the flavour, by allowing the seasoning to adhere to the chips. Furthermore, the protein content present in the nixtamalized maize chips was comparable to that of the commercial chips, suggesting that the maize chips also provide similar nutritional benefits. The chips also promote digestive health and prolong satiety due to its higher insoluble fibre content when compared to popcorn. Additionally, the mineral analysis of the maize chips indicated that it had low levels of calcium, magnesium, and potassium, while the sodium levels were within regulations for South Africa. However, the phosphorus content was much higher than the rest of the minerals. These minerals are essential for maintaining good health and are crucial for various bodily functions such as building strong bones, regulating blood pressure, and supporting the nervous system. Thus, the promising mineral content of the maize chips renders them an excellent snack option for consumers who are looking to incorporate nutrient-dense foods into their diet. It can further be concluded that the careful selection of ingredients during the development process, as well as extensive sensory testing, could result in the chips achieving a high level of consumer acceptance, with a 75.0% or even higher JAR rating. These results demonstrated that the chips could be considered as a viable alternative to commercial maize chips, as well as meeting the expectations and preferences of South African consumers. In this way, the chips might offer a healthier and more flavourful option to traditional maize chips.

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CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

The final chapter of this study provides a comprehensive conclusion of the most significant findings. In addition, it puts forth recommendations for future research pertaining to South African consumers' acceptance and attitudes towards nixtamalization and novel nixtamalized maize products. Additionally, this chapter aims to draw a definitive conclusion, regarding the potential nutritional advantages that nixtamalization may offer, to newly developed maize products.

6.2 SUMMARY OF THE FINDINGS

In the discussion below, a comprehensive summary of each objective will be provided, affirming that the study successfully achieved the objectives outlined in chapter one.

6.2.1 OBJECTIVE 1: *Conducting a comprehensive literature review on nixtamalization and maize, and exploring the potential for introduction in South Africa.*

Maize plays a significant role as a staple crop in Africa, particularly South Africa. Maize not only serves as a primary source of food, but also as a means of alleviating food insecurity and contributing to the South African economy. However, literature suggests that maize provides an unbalanced supply of essential nutrients. This can lead to nutrition insecurity among those who consume it, without other nutritionally dense foods. This realisation prompted the researcher to investigate methods that would address these issues. Nixtamalization, a processing technique that can be easily carried out with conventional household cooking equipment, served as the study's conceptual foundation. According to academic literature, nixtamalization enhances the nutritional value of maize, by releasing bound nutrients. Additionally, this technique is purported to prolong post-harvest safety, by significantly decreasing mycotoxins. Notwithstanding the ample corpus of literature available on nixtamalization, limited research has been conducted on its implementation and feasibility within the South African context. The researcher was aware that introducing a novel processing technique in a country, where it is unfamiliar, would require consumer acceptance and positive attitudes, for effective consideration and implementation. Thus, acceptance and attitude were used as guiding principles in conducting the study. Accordingly, the focus was on developing maize products that would be acceptable to the South African consumer, as a means of introducing nixtamalization. Therefore, the inception of this research was predicated from the first objective of the study.

6.2.2 OBJECTIVE 2: *Development of novel nixtamalized maize products that are acceptable to South African consumers.*

The study's second objective was to assess the acceptability of the nixtamalization process among South African consumers. In pursuit of this objective, the researcher developed novel maize products, using the nixtamalization process. During the product development phase, the researcher incorporated ingredients that were familiar to South African consumers, in each product's formulation. Three products were developed: a maize nugget; a maize patty; and a maize chip. All three products went through sensory analysis, to determine which could be a viable product for the South African consumer. The Just-About-Right scale and 9-point hedonic scale were employed to investigate the level of readiness, as well as acceptance of these products. Resultantly, the maize chips demonstrated significantly more satisfactory outcomes, in comparison to the other two products. Nonetheless, the unappealing appearance and taste of the chips persisted as dissatisfactory attributes, and hence, its formulation required improvement to achieve consumer acceptance. Consequently, the chips underwent improvement in duplicate: (i) improvement by increasing frying time, in order to darken the chip; and (ii) flavouring the chips with a seasoning that imparted a colour, which represented said flavour. The chutney-flavoured chip reached acceptance by 75.0% of consumers in its JAR scaling. These results and findings, thus, indicated the importance that sensory parameters play in the overall acceptance of new food products and, especially, in developing acceptable nixtamalized maize products.

6.2.3 OBJECTIVE 3: *Determination of consumer attitudes, knowledge and awareness towards nixtamalization, as well as newly developed nixtamalized maize products.*

The third objective of the study was to determine consumer's attitudes, knowledge and awareness toward nixtamalization, as well as towards the novel products that were developed through this process. To achieve this, an electronic questionnaire was used to collect relevant data. Respondents completed the questionnaire, after sensorily evaluating a novel nixtamalized maize chip. Their knowledge and experience with a nixtamalized product, during sensory tasting, were used as the basis for completing the questionnaire, to determine their attitudes. The findings indicated that the respondents had a favourable perception of the sensory attributes of the tasted product and, therefore, expressed their willingness to consume, purchase and prepare it for their friends and family. Additionally, the study revealed that the respondents displayed a keen interest in acquiring knowledge about food safety processing techniques, such as nixtamalization, which would enhance the safety of maize for consumption. The safety aspect of maize was identified as a crucial factor that would influence their future willingness to consume nixtamalized maize. Furthermore, respondents also exhibited a willingness to try out new food products, with factors, such as health benefits, general availability, price, promotions and usage by friends and family, being important considerations in their decision-making process. The study's findings indicated that the sampled population demonstrated a positive attitude to the introduction of nixtamalization in South Africa, as well as to newly developed nixtamalized maize products.

6.2.4 OBJECTIVE 4: *To determine the nutritional content of the accepted product developed in 'objective 2', as well as comparing it to similar non-nixtamalized products.*

The fourth objective of the study aimed to ascertain the nutritional composition of the product that was deemed acceptable through the sensory evaluation, conducted in the second objective. Nutritional analysis was conducted to assess the nutrient content of the nixtamalized product, as well as compare it to other products within the same category or common everyday products, to draw reference to. The observation that emerged was that the cooking method employed had a considerable influence on foods nutrient content, as demonstrated by the study. In the case of the nixtamalized maize chips, the deep-frying method employed resulted in higher energy content, compared to the two commercial chips. Additionally, the fat and protein content of the nixtamalized maize chips were comparable to the two commercial chips. However, an important aspect to note was that the nixtamalized maize chips had a higher concentration of unsaturated fatty acids, compared to SAFAs. This observation underscored how the choice of the cooking medium could influence the nutrient content of food products. Regarding the mineral content, the nixtamalized maize chips were found to have a slightly higher sodium content, but remained within the permissible limit, stipulated by the South African salt legislation. The nixtamalized maize chips contained favourable amounts of essential minerals, such as calcium, magnesium, potassium and phosphorus. It is, therefore, suggested that the use of nixtamalization in producing maize-based products, either at household or industry level, has the potential to mitigate the challenge of nutrition insecurity, which is prevalent among South African consumers, who mainly consume maize as their staple food.

6.3 CONCLUSION

The final objective of the study was to present a clear and informative conclusion of the findings. Therefore, it could be concluded that the implementation and acceptability of nixtamalization in South Africa has the potential to make a considerable impact on the future consumption of maize amongst consumers. With the aim of enhancing the nutritional value of maize, this study successfully developed novel nixtamalized maize products that were acceptable to South African consumers. The findings indicated that nixtamalization is a viable processing technique, for enhancing the nutrient value of maize, as well as developing novel maize products with the benefits that come with nixtamalization. Moreover, the study revealed that South African consumers had a positive attitude towards nixtamalization, and were willing to consume and prepare novel nixtamalized maize products themselves. The nutritional analysis further emphasised the potential health benefits of nixtamalization. Therefore, this study serves as a valuable contribution to the food processing industry, both at the household and industry levels, and its findings are crucial for future research on nixtamalization in South Africa.

6.4 RECOMMENDATIONS

It is imperative to note that the present study represents a preliminary exploration into the acceptability of nixtamalization, for enhancing the nutritional quality of maize-based products in South Africa. Although the current study shows encouraging results, the researcher recommends that further research, on a larger scale, is warranted. This would fully elucidate the potential impact of nixtamalization on the nutritional value of maize products and assess the feasibility of scaling up the nixtamalization processes, for commercial production. Undoubtedly, the potential impact of this study on the future prospects of maize and maize products in South Africa cannot be overstated, particularly with respect to addressing malnutrition among low-income populations.

Given these factors, the current research presents a significant milestone in achieving the full potential of nixtamalization, as a means of value-adding to maize-based products in South Africa.

APPENDIX A: ETHICAL APPROVAL

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA

UFS·UV
RESEARCH DEVELOPMENT
NAVORSINGSONTWIKKELING

Environment & Biosafety Research Ethics Committee

11-May-2021

Dear **Dr Alba Du Toit**

Project Title: **Promotion of an agro-processing technique for Southern Africa: Nixtamalization**

Department: **Consumer Science Department (Bloemfontein Campus)**

APPLICATION APPROVED

This letter confirms that this research proposal was given ethical clearance by the Biosafety & Environmental Research Ethics Committee of the University of the Free State.

Your ethical clearance number, to be used in all correspondence is: **UFS-ESD2021/0085/21**

Please note the following:

1. **This ethical clearance is valid for five years from the issuance of this letter.**
2. **If the research takes longer than five years to complete, please submit a Continuation Report to the Ethics Committee before ethical clearance expires.**
3. **If any changes are made during the research process (including a change in investigators), please inform the Ethics Committee by submitting an Amendment.**
4. **When the research is concluded, please submit a Final Report to the Ethics Committee.**

Approved

Thank you for your application and we wish you well in all of your research endeavours.

Yours Sincerely

Prof. RR (Robert) Bragg
Chairperson: Environment & Biosafety Research Ethics Committee
University of the Free State

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GENERAL/HUMAN RESEARCH ETHICS COMMITTEE (GHREC)

02-Aug-2021

Dear Dr Alba Du Toit

Application Approved

Research Project Title:
Promotion of an agro-processing technique for Southern Africa: Nixtamalization

Ethical Clearance number:
UFS-HSD2021/0668

We are pleased to inform you that your application for ethical clearance has been approved. Your ethical clearance is valid for twelve (12) months from the date of issue. We request that any changes that may take place during the course of your study/research project be submitted to the ethics office to ensure ethical transparency. furthermore, you are requested to submit the final report of your study/research project to the ethics office. Should you require more time to complete this research, please apply for an extension. Thank you for submitting your proposal for ethical clearance; we wish you the best of luck and success with your research.

Yours sincerely

Dr Adri Du Plessis
Chairperson: General/Human Research Ethics Committee

Adri du Plessis
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APPENDIX B: JAR BALLOTS

UNIVERSITY OF THE FREE STATE
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NATURAL AND AGRICULTURAL SCIENCES
NATUUR- EN LANDBOUWETENSKAPPE

JAR TEST: Nuggets

Gender ______ **Date** ______

Age ______

INSTRUCTIONS Please indicate with an X your opinion on the JAR scale. Then tick how much you like the overall acceptability of the sample on the hedonic scale.			
Sample code:			
Aroma (Spicy)		**Appearance (Colour)**	
Much too spicy	☐	Much too brown	☐
Somewhat too spicy	☐	Somewhat too brown	☐
Just about right	☐	Just about right	☐
Somewhat too bland	☐	Somewhat dull	☐
Much too bland	☐	Much too dull	☐
Taste (Savoury)		**Mouthfeel (Crunchy)**	
Much too savoury	☐	Much too crunchy	☐
Somewhat too savoury	☐	Somewhat too crunchy	☐
Just about right	☐	Just about right	☐
Somewhat too bland	☐	Somewhat too soft	☐
Much too bland	☐	Much too soft	☐

Overall acceptability

1	2	3	4	5	6	7	8	9
Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

THANK YOU!!

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NATUUR- EN LANDBOUWETENSKAPPE

JAR TEST: Patties

Gender ______ **Date** ______

Age ______

INSTRUCTIONS
Please indicate with an X your opinion on the JAR scale. Then tick how much you like the overall acceptability of the sample on the hedonic scale.

Sample code:	
Aroma (Spice)	**Appearance (Colour)**
Much too spicy ☐	Much too brown ☐
Somewhat too spicy ☐	Somewhat too brown ☐
Just about right ☐	Just about right ☐
Somewhat too bland ☐	Somewhat dull ☐
Much too bland ☐	Much too dull ☐
Taste (Savoury)	**Mouthfeel (gritty)**
Much too savoury ☐	Much too smooth ☐
Somewhat too savoury ☐	Somewhat too smooth ☐
Just about right ☐	Just about right ☐
Somewhat too bland ☐	Somewhat too gritty ☐
Much too bland ☐	Much too gritty ☐

Overall acceptability

1	2	3	4	5	6	7	8	9
Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

¡THANK YOU!!

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UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA

UFS·UV
NATURAL AND AGRICULTURAL SCIENCES
NATUUR- EN LANDBOUWETENSKAPPE

JAR TEST: CORN CHIP

Age:		Date:	
Gender:		Home Language:	

INSTRUCTIONS
Please indicate with an X your opinion on the JAR scale. Then tick how much you like the overall acceptability of the sample on the hedonic scale.

Aroma: corn/starch		Appearance - oily	
Much too strong	☐	Much too oily	☐
Somewhat too strong	☐	Somewhat too oily	☐
Just about right	☐	Just about right	☐
Somewhat too low	☐	Somewhat oily	☐
Much too low	☐	Not oily	☐
Taste: savoury		**Mouthfeel: crispy**	
Much too savoury	☐	Much too crispy	☐
Somewhat too savoury	☐	Somewhat too crispy	☐
Just about right	☐	Just about right	☐
Somewhat too bland	☐	Somewhat too soft	☐
Much too bland	☐	Much too soft	☐

Overall acceptability

1	2	3	4	5	6	7	8	9
Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

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APPENDIX C: QUESTIONNAIRE

DRAFT

EvaSys	Promotion of agro-processing through the process of nixtamalization	Electric Paper

Taylon Colbert

Sensory analysis of nixtamalized maize products

Mark as shown: ☐ ☒ ☐ ☐ ☐ Please use a ball-point pen or a thin felt tip. This form will be processed automatically.

Correction: ☐ ■ ☐ ☒ ☐ Please follow the examples shown on the left hand side to help optimize the reading results.

1. Section A: Demographic information

1.1	Which gender do you identify with?	☐ Male	☐ Female	☐ Other
1.2	Please select your age group:	☐ 18-24 years	☐ 25-25 years	☐ 36-59 years
		☐ 60 and older		
1.3	What language do you speak at home?	☐ Sesotho	☐ IsiXhosa	☐ IsiZulu
		☐ Setswana	☐ Afrikaans	☐ English
		☐ Tsivenda	☐ SiSwati	☐ Tsonga
		☐ Ndebele		
1.4	What is your highest level of education/schooling?	☐ Never been to school	☐ Attended secondary school (grade 8-11) but never completed Matric	☐ Completed Matric
		☐ Currently studying to obtain a tertiary qualification	☐ Attended tertiary education but did not complete the course	☐ Obtained a tertiary qualification (for example: a certificate, diploma or Bachelors degree)
		☐ Postgraduate degree (Honours/ Masters/PhD)		
1.5	In which province did you grow up/spend most amount of time between birth and 18 years of age?	☐ Western Cape	☐ Northern Cape	☐ Northwest
		☐ Kwa-Zulu Natal	☐ Limpopo	☐ Free State
		☐ Mpumalanga	☐ Gauteng	☐ Eastern Cape
		☐ I did not grow up in South Africa		

2. Acceptability of product tasted

On a scale of 1-5, indicate how much you liked the following attributes of the product, with 1 indicating that you "do not like it at all", and 5 indicating that you "liked it very much".

		Do not like it at all				Liked it very much
2.1	I liked appearance of the product.	☐	☐	☐	☐	☐
2.2	I liked the aroma of the product.	☐	☐	☐	☐	☐
2.3	I liked the texture of the product.	☐	☐	☐	☐	☐
2.4	I liked how the product tasted.	☐	☐	☐	☐	☐

On a scale of 1-5, rate whether you agree with the following statements, with 1 indicating that you do not agree at all, and 5 indicating that you completely agree with the statement.

		Strongly disagree	Disagree	Neither agree or disagree	Agree	Completely agree
2.5	I will eat this food product again.	☐	☐	☐	☐	☐

F24739U0P1PL0V0 14.09.2021, Page 1/4

DRAFT

2. Acceptability of product tasted [Continue]

2.6	I will purchase this product in a grocery store.	☐	☐	☐	☐	☐
2.7	I will prepare this product for my family.	☐	☐	☐	☐	☐
2.8	I will order this product in a restaurant.	☐	☐	☐	☐	☐
2.9	I will recommend this product to my friends and family.	☐	☐	☐	☐	☐

3. Knowledge and awareness of the safety of maize

On a scale of 1-5, rate whether you agree with the following statements, with 1 indicating that you "do not agree at all", and 5 indicating that you "completely agree" with the statement.

		Strongly disagree	Disagree	Neither agree or disagree	Agree	Completely agree
3.1	I only eat white maize.	☐	☐	☐	☐	☐
3.2	I will eat maize of others colours in addition to white and yellow maize.	☐	☐	☐	☐	☐
3.3	Both white and yellow dried maize are safe to eat.	☐	☐	☐	☐	☐
3.4	I will eat and prepare any colour maize if I know that they are safe to eat.	☐	☐	☐	☐	☐
3.5	I want to know more about a process that will make stored maize safe to eat.	☐	☐	☐	☐	☐
3.6	I am interested in learning about maize that is safe to eat after being stored for a long time.	☐	☐	☐	☐	☐

4. Consumer awareness of maize as a food source

The image below show differently coloured maize

Please indicate your experience with maize by indicating the extent to which the statements reflect your experience with different colours of maize kernels.

4. Consumer awareness of maize as a food source [Continue]

		Never	At least once in my life	A few times in my life	At least once during the past year	More than once in the past year
4.1	I have seen maize of different colours in person.	☐	☐	☐	☐	☐
4.2	I have prepared meals/food with maize kernels/products of different colours.	☐	☐	☐	☐	☐
4.3	I have eaten meals/food with maize of other colours than white maize.	☐	☐	☐	☐	☐
4.4	I have cultivated maize of other colours for human consumption.	☐	☐	☐	☐	☐

Please indicate to what extent you agree or disagree with each of the following statements, "I will only eat nixtamalized maize products when..." with 1 indicating that you "strongly disagree", and 5 indicating that you " completely agree":

		Strongly disagree	Disagree	Neither disagree or agree	Agree	Completely agree
4.5	...these products are given to me for free.	☐	☐	☐	☐	☐
4.6	...I have more knowledge about the health benefits of nixtamalized maize than I do at present.	☐	☐	☐	☐	☐
4.7	...it is available for purchase in my local supermarket.	☐	☐	☐	☐	☐
4.8	...my friends and family use nixtamalized maize products.	☐	☐	☐	☐	☐
4.9	...nixtamalized maize flour is cheaper than other maize meal or maize kernels.	☐	☐	☐	☐	☐
4.10	...nixtamalized maize meal is similarly priced compared to other maize meal.	☐	☐	☐	☐	☐
4.11	...when I do not have access to any other food.	☐	☐	☐	☐	☐

5. Knowledge and awareness of new food products and trends

How important are the following considerations when deciding to introduce a new food item into your diet, with 1 indicating "not important at all" and 5 indicating "extremely important.

		Not important at all				Extremely important
5.1	The health benefits of the food item.	☐	☐	☐	☐	☐
5.2	The general availability of the food item.	☐	☐	☐	☐	☐
5.3	The trendiness of the food item.	☐	☐	☐	☐	☐
5.4	The price of the food item is similar when compared to other products.	☐	☐	☐	☐	☐
5.5	The price of the new food item is cheaper when compared to other similar products.	☐	☐	☐	☐	☐
5.6	Promotion of the food item. For example: being given free samples to try.	☐	☐	☐	☐	☐

5. Knowledge and awareness of new food products and trends [Continue]

5.7	The use of the food item by friends and family.	☐	☐	☐	☐	☐

Please indicate how often you:

		Never	Rarely	Sometimes	Regularly	Always
5.8	Experiment with unusual ingredients in meals that you prepare.	☐	☐	☐	☐	☐
5.9	Substitute conventional products with new or unfamiliar products in recipes.	☐	☐	☐	☐	☐
5.10	Keep your eyes open for new food products to try.	☐	☐	☐	☐	☐
5.11	Try new food products in stores.	☐	☐	☐	☐	☐
5.12	Try out new recipes.	☐	☐	☐	☐	☐
5.13	Try out new food trends.	☐	☐	☐	☐	☐
5.14	Get excited when stores introduce new food products for you to try.	☐	☐	☐	☐	☐

Thank you for your participation

APPENDIX D: CONSENT FORM

RESEARCH STUDY ON THE CONSUMER ACCEPTABILITY OF MAIZE PRODUCTS

Information and consent form

Dear respondent,

You are invited to participate in this research project. The study investigates the consumer acceptability and sensory attributes of maize products. Should you have any questions or concerns about the study, you can contact Carina Bothma at BothmaC@ufs.ac.za, Liezl van der Walt at DuToitL1@ufs.ac.za. The findings of the study will be disseminated for a Masters in Consumer Science and in academic journals.

The main aspects relating to the study discussed in the information sheet are the following:

This study has received approval from the General Human Research Ethics Committee of the University of the Free State.
Your participation only requires of you to complete the online questionnaire that follows if you consent to participate in the study as well as taste the samples provided to you by trained sensory assistants. It will take not more than 15 minutes to complete the questionnaire / tasting.
The completion of the questionnaire and tasting poses no inconvenience or any risk to a participant.
Participants can complete the online questionnaire at a time that does not lead to loss of work time.
Participation in the study is voluntary and you are under no obligation to consent to participation. You are free to withdraw at any time and without giving a reason during the completion of the tasting and are free to leave the sensory tasting area.
The questionnaire does not include any question that provides information that can be used to identify you as a respondent participant and your participation is anonymous.
The electronically captured data from the completed online questionnaires and tasting data will be stored on a password-protected computer.
The findings of the study will only be used for the disclosed purposes, that is, the dissemination of the findings only for academic purposes.

Thank you in advance for your willingness to participate in the research study.

Sincerely,

Liezl van der Walt (Sensory lab manager)
Carina Bothma (Sensory analyst)
Almaré de Bruin (Sensory lab assistant)

CONSENT TO PARTICIPATE IN THIS STUDY

I confirm that the person asking my consent to take part in this research has informed me about the nature, procedure, potential benefits, and anticipated inconvenience of participation. I have read and understood the study as explained on the previous page. I had the opportunity to ask questions and I am prepared to participate in the study. I understand that my participation is voluntary and that I am free to withdraw at any time without penalty. I am aware that the findings of this study will be anonymously processed.

☐ I confirm

Please type your name and surname below to consent to participate:

Short answer text

Please specify if you have any allergies or dietary restrictions? *

- [ ] Vegetarian
- [ ] Vegan
- [ ] Kosher
- [ ] Halal
- [ ] Gluten-free
- [ ] Nut-allergy
- [ ] Milk (lactose)
- [ ] Eggs
- [ ] Wheat
- [ ] Fish (Shellfish)
- [ ] None
- [ ] Other...