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PRESERVATION OF TSHIDZIMBA, A CEREAL-LEGUME COMPOSITE PORRIDGE, THROUGH FERMENTATION, CANNING AND DRYING

BY

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SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

M INST AGRAR (FOOD PROCESSING)

IN THE
DEPARTMENT OF FOOD SCIENCE
FACULTY OF NATURAL, AGRICULTURAL & INFORMATION SCIENCES

UNIVERSITY OF PRETORIA
PRETORIA
REPUBLIC OF SOUTH AFRICA

2001

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I declare that the dissertation herewith submitted for the degree of M Inst Agrar (Food Processing) at the University of Pretoria, has not previously been submitted by me for a degree at any other University or institution of higher education.

Signature:

Date:

ACKNOWLEDGEMENTS

My heartfelt gratitude and appreciation go to the following individuals and organisations for their help and assistance with this project:

Prof. JRN Taylor, my supervisor, for his guidance, leadership, encouragement and constructive, critical review of this dissertation. Thanks for your patience and for not giving up on me.

Prof. A Minnaar, my co-supervisor, for her technical support, constructive criticism and invaluable advice during the last part of this project.

The National Research Foundation (NRF) for much valued financial assistance.

Friends and colleagues in the Department of Food Science, University of Pretoria for their encouragement, assistance and willingness to listen.

My family, for their encouragement and support throughout my studies.

Most of all to God Almighty. Thanks for coming through for me.

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ABSTRACT

PRESERVATION OF *TSHIDZIMBA*, A CEREAL-LEGUME COMPOSITE PORRIDGE, THROUGH FERMENTATION, CANNING AND DRYING

by

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Traditional African foods are often rich in nutrients and play an important role in increasing variety in diets of people in rural areas. *Tshidzimba* is popular amongst the Vhavenda of South Africa. It is made from maize samp, milled peanuts and salt. However, it has a very short shelf life when stored at ambient temperature. Canning, drying and fermentation of *Tshidzimba* were investigated to increase shelf-life. Factors investigated were microbiological quality, nutrient content (in terms of fat and protein content), levels of essential amino acids, water activity and sensory acceptability.

Unpreserved *Tshidzimba* had very high total plate counts, yeasts and moulds after 3 days of storage at 25°C. Fermentation reduced the yeasts and moulds by 10^2 and total plate counts by 10^3 after 21 days of storage at 25°C from those of unpreserved *Tshidzimba*. Drying reduced the yeasts and moulds by 10^4 and total plate counts by 10^5 after 21 days

of storage at 25°C. Anaerobic spore formers were not detected in canned *Tshidzimba* after 21 days of storage at 25°C.

Drying reduced the fat content probably due to fat oxidation at the elevated drying temperature (50°C). However, in general the preservation methods had little effect on the general nutrient content of *Tshidzimba*.

Tshidzimba protein showed low lysine value compared to the estimates of amino acid requirements for infants. For *Tshidzimba* to be a good source of nutrients for infants, fortification with a higher proportion of legume grains is recommended. Drying seemed to increase lysine (2.61 g/100 g protein) compared to that of unpreserved *Tshidzimba* (2.28 g/100 g protein), while canning reduced lysine (1.97 g/100 g protein), probably due to its participation in Maillard reaction at the high canning temperature (116°C/70 min). Fermentation increased methionine content probably due to fermentative microorganisms, which are known to produce some amino acids while fermenting food products. Canning seemed to have reduced the methionine content possibly due to Maillard reaction.

Consumer panellists indicated that of the preserved *Tshidzimba*, dried *Tshidzimba* had high acceptance compared to canned and fermented *Tshidzimba*. Some panellists disliked the sour taste of fermented *Tshidzimba*. Dried *Tshidzimba* was perceived to have a firmer texture compared to unpreserved *Tshidzimba*. Further research could help to determine the appropriate temperature/time combination that can least affect the texture of dried *Tshidzimba*.

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OPSOMMING

BEWARING VAN *TSHIDZIMBA*, GRAAN-LEGUMEN SAAMGESTELDE PAP, DEUR FERMENTASIE, BLIKKIESKOS EN VERDROGING.

deur

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Tradisionele Afrika kossoorte is ryk aan voedingstowwe en speel ’n toenemende belangrike rol in verskillende dieëte van mense in landelike gebiede. *Tshidzimba* is populêr tussen die Vhavenda in Suid-Afrika. Dit word gemaak van mielie samp, gemaalde grondboontjies en sout. Dit het ongelukkig ’n kort stoorlewe in warm temperature. Om die stoorlewe van *Tshidzimba* te verleng is verskeie maniere probeer naamlik fermentassie, verdroging en verpakking in blikkies. Faktore wat ondersoek is was mikro-biologiese kwaliteit, veodingswaarde inhoud (in terme van vet en proteine inhoud), vlakke van essensieule amino sure, water aktiwiteit en sensoriese aanvaarbaarheid.

Angepreserveerde *Tshidzimba* het baie hoë totale plaat tellings. Na twee dae teen 25°C kom suurdeeg en skimmel voor. Fermentasie het die suurdeeg en skimmel tot 10^2 verminder en totale plaat tellings tot 10^3 na 21 dae van stoortyd teen 25°C van die

ongepreserveerde *Tshidzimba*. Verdroging het die suurdeeg en skimmel tot 10^4 verminder en totale plaat tellings tot 10^5 na 21 dae van stoortyd teen 25°C. Anarobiese spoor formers kon nie in geblikte *Tshidzimba* na 21 dae se spoortyd teen 25°C opgespoor word nie.

Verdroging het die vet inhoud verminder. Dit is moontlik te danke aan vet oksiedasie teen 'n verhoogde verdrogings temperature van 50°C. Oor die algemeen het die preserverings metodes min effek op die algemene voedingswaarde inhoud van *Tshidzimba* gehad.

Tshidzimba proteine het 'n lae lysien gehalte vergeleke met estimasies van aminosuur vereistes vir baba's. Vir *Tshidzimba* om 'n goeie bron van voedingswaarde vir baba's te wees, word 'n hoër proporsie legumen korrels aanbeveel. Verdroging blyk om lysien te verhoog (2.61 g/100 g/proteine), terwyl geblikte *Tshidzimba* lysien verlaag het tot (1.97 g/100 g/proteine). Dit is heel moontlik as gevolg van die Maillard reaksie by die hoê temperatuur van (116°C/70 min) tydens verblikking. Fermentasie verhoog die metionien inhoud. Dit is moontlik as gevolg van fermentatiewe mikro-organismes, wat bekend is daarvoor om amino sure te vervaarding terwyl kos produkte fermenteer. Geblikkte *Tshidzimba* blyk die metionien inhoud te verlaag, moontlik as gevolg van die Maillard reaksie.

Verbruiker paneelde het aangedui dat die gepreserveerde *Tshidzimba*, gedroogde *Tshidzimba*, meer aanvaarbaar is as geblikkte en gefermenteerde *Tshidzimba*. Sommige van die paneellede het nie van die suur smaak van gefermenteerde *Tshidzimba* gehou nie. Gedroogde *Tshidzimba* word beskou as 'n fermer komposisie te hê as die ongepreserveerde *Tshidzimba*. Verdere studie kan help om vas te stel wat die korrekte temperatuur/tyd kombinasie moet wees om die minste effek op die komposisie/samestelling van gedroogde *Tshidzimba* te hê.

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1. INTRODUCTION

Protein deficiency is a major problem in many rural African communities. Animal proteins, from meat and dairy products, are either too expensive, or simply not available due to natural disasters, such as droughts (Vorster & Venter, 1993). To meet this protein deficiency in African diets, cereals and legumes, which are generally the common staple food, have to be used.

Tshidzimba is a composite food product made from maize grits (otherwise known as *samp*) and legumes. The product is consumed in Venda, an area in the Northern Province of South Africa. *Tshidzimba* is consumed by the Vhavenda people who are natives of this area. The legumes used are generally peanuts (*Arachis hypogaea*). Yellow or white maize (*Zea mays*) may be used. Although the term "*Tshidzimba*" is Venda, the composite is a common traditional food in many parts of Africa, for example, in Nigeria the product is called *Egbo* (Oyeleke, 1992).

Tshidzimba is prepared by mixing maize *samp* and powdered peanuts. The ingredients are simmered until a thick paste is formed (Mukwevho, R.R., 1998, Sister, Personal Communication). According to Bressani (1993) the cereal and legume complement each other in terms of essential amino acids, fats and vitamins. Maize is high in sulphur amino acids (cysteine and methionine) but low in lysine, tryptophan and fats (Kent & Evers, 1994) while oilseed legumes are generally high in lysine and fats but low in sulphur amino acids (Bressani, 1993). The cereal-legume composite has many more improved qualities than either one of the two individual components, i.e. cereal or legume alone. Thus, *Tshidzimba* appears to have superior appearance, texture and flavour qualities than maize and legume alone.

However, cereal-legume composites such as *Tshidzimba* are very perishable (short shelf-life), and many of the rural communities do not have refrigeration facilities or electricity. Canning, drying and fermentation are preservation techniques that can be used to extend the shelf-life of perishable foods at ambient temperature.

These treatments reduce the microbial load and ensure safety of the product. This would eliminate seasonal variations in food availability by ensuring long term shelf-life (Jackson & Shinn, 1979).

2. LITERATURE REVIEW

2.1 Structure and nutritional properties of maize

2.1.1 Grain morphology

Hoseney (1994) states that a maize kernel is a caryopsis, a comparatively large, dry, one-seeded fruit, in which the seed (consisting of embryo, endosperm and remnants of the seed coat and nucellus) is fused to the adhering pericarp to form a single grain. Mature kernels consist of:

- a germ (embryo)
- endosperm
- pericarp (hull or bran); and
- pedicel (tip cap).

Table 1 shows the relative proportions of component parts of yellow dent maize kernels. In Figure 1 a longitudinal section of a maize kernel is shown.

The germ may represent 10 to 17% of the kernel weight, depending on the type of maize (Salunke, Chavan & Kadam, 1985). The average germ of most normal dent maize hybrids is around 10% (Table 1). The scutellum (90%) and the embryonic axis are the two major parts of the germ. The scutellum is of primary interest from a nutritional viewpoint because of the large proportion of oil-storage parenchyma, which it contains. The germ also makes out about 22% of the total protein of the mature kernel and the protein is of better quality than that from the endosperm.

Table 1: Typical yellow dent maize composition of hand dissected kernel parts (Glover & Mertz, 1987).

Fraction	**Whole Kernel**	**Starch (%)**	**Protein (%)**	**Fat (%)**	**Sugar (%)**	**Ash (%)**
Endosperm	82.6	87.6	7.9	0.83	0.62	0.33
Germ	11.1	8.0	18.3	33.50	10.50	10.60
Pericarp	5.4	7.2	3.6	1.030	0.36	0.85
Tip Cap	0.8	5.3	9.1	3.80	1.61	1.59

The endosperm of the kernel is of prime importance as a source of energy in food, feed and industrial products (Glover & Mertz, 1987). The mature endosperm of normal dent maize is 82% of the kernel weight. The aleurone layer and the endosperm storage tissues consisting principally of granular starch, granular protein bodies and matrix protein are the two major parts of the endosperm. Starch granules of the maize endosperm are embedded in a protein network. A large amount of protein is located in the sub-aleurone region (Hoseney, 1994).

The pericarp (transformed ovary wall) is composed of an outer layer of dead, elongated, thick-walled cells forming a tough, dense tissue. Beneath this layer of dead cells is a spongy layer of cells. A thin rubberized membrane known as the testa (seed coat) comes next. Beneath the testa lies a cell layer known as the aleurone tissue (Salunke *et al.*,1985). The tip cap is the remnant of the tissue connecting the kernel to the cob.

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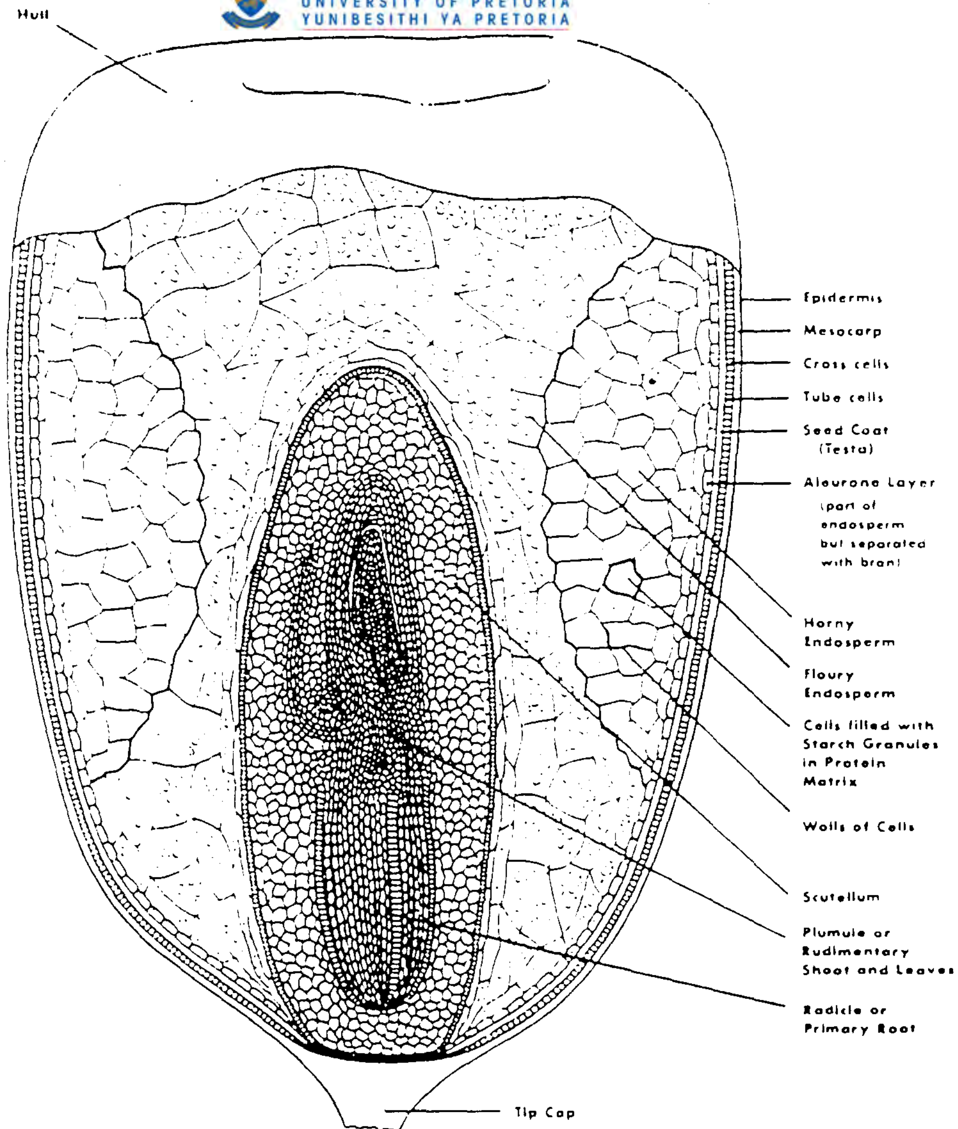

Fig. 1 Longitudinal section of a maize kernel (Hoseney, 1994)

2.1.2 Nutritional properties of maize

Maize has a lower nutritive value than that of other cereals such as wheat, in particular being deficient in the vitamin niacin and having a relatively low content of protein (deficient in the amino acids lysine, as is wheat protein) and tryptophan (Kent & Evers, 1994). Because maize has a relatively low protein content, yellow maize is mainly included as an energy source in feed rations. It is, however, used in such large quantities that the significance of the protein content and protein quality of the yellow maize especially, cannot be underestimated (Cronjé, 1989).

The protein content of dry-milled maize flour is about 7% (Kent & Evers, 1994). In order to make maize products satisfactory as the main item of a diet, the addition of lysine, tryptophan, thiamin, niacin and riboflavin would be desirable.

Glover and Mertz (1987) state that the major component of the whole maize kernel is starch. Protein and lipids are present at much lower levels. However, the level of components changes in some of the fractions of the maize kernel. Thus, the germ contains the three major components in a reverse ratio, and is rich in minerals. The endosperm accounts for about 98% of the starch, 75 to 80% of the protein and 15% of the lipids in the whole kernel. The nature of those chemical components is given below.

2.1.2.1 Carbohydrates

Starch is the primary carbohydrate in maize grain and makes up 60-80% of the normal (non- waxy) kernels (Klopfenstein & Hoseney, 1995).

Starch is a basically polymer of α-*D*-glucose. Chemically, at least two types of polymers are distinguishable: amylose, a linear polymer and amylopectin, which is highly branched. Amylose is generally assumed to be a linear polymer of α-*D*-glucose linked α-1,4, while amylopectin is composed of α-*D*-glucose linked primarily by α- 1,4 bonds. Normal dent and flint maize contain about 27% amylose and 73% amylopectin. Amylose contains about 1000 glucose units whereas amylopectin contains about 40 000 or more units. A number of maize endosperm mutants and combinations of mutants control various sizes and shapes of starch granules (Glover & Mertz, 1987).

2.1.2.2 Proteins

Maize is reported to contain about 10% by mass of protein (Kent & Evers, 1994). Values reported may vary due to differences in variety and agronomic conditions under which the crop is grown. The following distribution of N was found in maize; endosperm 81.2%, embryo 15.5% and pericarp 3.3% (Salunke *et al.*, 1985). Little is known about the

proteins of the germ. About 40% of the proteins consist of albumins, globulins and nucleoproteins. The germ proteins are much higher in lysine and tryptophan than endosperm proteins (Glover & Mertz, 1987).

The proteins of the endosperm have been studied more intensively than the germ proteins. About 44% of the proteins in the endosperm are alcohol-soluble, 26% acid-soluble and 28% alkali-soluble. Five protein fractions have been obtained: albumins, zein, zein-like, glutelin-like and glutein.

2.1.2.3 Lipids

Glover and Mertz (1987) report that the average hybrid maize kernel contains about 5% oil, 85% of which is in the embryo. The most abundant fatty acids in maize oil is linoleic acid, comprising about 60% of the total fatty acids.

2.1.2.4 Minerals

Table 2 shows the range and average content of the major minerals in whole maize.

Table 2: Mineral content of maize grain (adapted from Glover & Mertz, 1987).

Mineral	Percentage (%)
Calcium	0.03
Phosphorus	0.32
Potassium	0.35
Magnesium	0.17
Iron	0.003
Sodium	0.01
Sulphur	0.12

2.1.2.5 **Vitamins**

Yellow maize contains about 490 IU of vitamin A activity per 100 g. White maize has practically no vitamin A activity. Both types of maize contain about 22 mg/kg of vitamin E (mainly in germ). Glover and Mertz (1987) stated that both maize types contain little or no vitamin K or D. As mentioned previously vitamin A also influences the colour.

Table 3 shows the approximate levels for water-soluble vitamins in whole maize grain.

Table 3: water-soluble vitamin levels in whole maize grain (Glover & Mertz, 1987)

Vitamins	**Level (mg/kg)**
Choline	537
Folic acid	0.2
Niacin	23
Pantothenic acid	5
Riboflavin	1
Thiamine	4
Pyridoxine	7
B_{12}	0

2.2 Structure and nutritional properties of peanuts

2.2.1 Seed structure

Seeds account for about 55 to 75% the weight of unhulled pods. Mature kernels consist of:

- pericarp (known as hull)
- cotyledons
- germ (axis)

2.2.2 Nutritional properties of peanuts

Peanut is a good source of proteins, lipids, dietary energy and crude fibre (Nwokolo, 1996). Table 4 shows the chemical composition of peanut components. The oil content of peanuts varies from 44.5-56.3%. This variation is due to seed size, variety, kernel position in pod (basal kernel has the highest oil content), and practices, such as irrigation and fertilisation.

Table 4. Chemical composition of peanut components (Rhee, 1985)

Components	Cotyledons (%)	Shells (%)	Testa (%)	Germ (%)
Moisture	5-8	-	9.0	-
Protein	25.4-33.8	4.8-7.2	11.0-13.4	26.5-27.8
Oil	44.5-56.3	1.2-2.8	0.5-1.9	39.4-43.0
Total carbohydrate	6.0-24.9	10.6-21.2	48.3-52.2	-
Reducing sugars	0.1-0.4	0.3-1.8	1.0-1.2	7.9
Disaccharides	2.9-6.4	1.7-2.5	-	12.0
Pentosans	2.2-2.7	16.1-17.8	-	-
Starch	0.9-5.3	0.7	-	-
Hemicellulose	-	10.1	-	-
Crude fibre	1.6-1.9	65.7-78.3	21.4-34.9	1.6-1.8
Ash	1.8-2.9	1.9-4.6	2.1	2.9-3.2

- Not provided

2.2.2.1 Carbohydrates

The cotyledons of peanuts naturally contain about 18% carbohydrates and the pericarp about 1%. The starch content of peanuts varies from 0.5 to 5% depending upon the type, growing conditions and maturity (Nwokolo, 1996). Sucrose is reported to constitute 4 to 7% of peanuts and testa-free peanuts are found to contain 2% cellulose according to Khalil and Chughtai (1983).

2.2.2.2 Proteins

Peanuts are reported to contain about 25-33% by mass of protein (Nwokolo, 1996). Values reported may vary due to differences in variety and agronomic condition under which the crop is grown. Peanut proteins contain all of the essential amino acids but are limiting in sulphur containing amino acids, the amounts available are lower than the maximum level the body needs to produce new protein. Because of their high protein content peanuts are considered members of "meat group".

2.2.2.3 Lipids

Peanuts naturally contain from 44-50% oil (Potter, 1986). Peanut oil is fairly stable in that the iodine number, saponification number, acetyl number and free-fatty acids do not change during heat treatment. The fatty acid profiles of raw peanuts, low-fat peanut flour and peanut butter (Table 5) confirm that peanut oil is an excellent source of mono- and polyunsaturated fatty acids exceeding the levels of these fatty acids in soybean and maize oil, but significantly lower than in sunflower seed oil or safflower oil (Nwokolo, 1996).

Table 5: Fatty acids content of peanut products (USDA, 1986 according to Nwokolo, 1996). Content (g/100 g product)

Fatty acids	Raw peanuts	Low-fat flour	Peanut butter
Saturated (total)	6.83	3.04	9.59
14:0	0.03	0.01	0.05
16:0	5.15	2.29	5.50
18:0	1.10	0.49	2.14
Mono-unsaturated (total)	24.43	10.87	23.58
16:1	0	0	-
18:1	23.76	10.57	22.90
20:1	0.66	0.30	0.62
Poly-unsaturated (total)	15.56	6.92	14.36
18:2	15.56	6.92	14.10
18:3	0	0	1.08

- Not provided

2.2.2.4 Minerals

According to Nwokolo (1996) peanuts are a good source of important dietary minerals such as potassium, phosphorus, magnesium and sulphur, but like in most legumes a proportion of their phosphorus may exist as phytic acids salts. These minerals are virtually unaffected by heating. Khalil and Chughtai (1983) state that there is a considerable variation in amount of ash from peanuts raised on different soil types.

2.2.2.5 Vitamins

There are several important vitamins in peanuts. The kernels are an excellent source of riboflavin, thiamine and niacin (Nwokolo, 1996). They also contain considerable vitamin E, but practically no vitamins A, C, or D. Appreciable amounts of B complex vitamins

and vitamin K are likely to be present. While a large portion of the thiamine is destroyed by roasting and even more by blanching, niacin, choline and riboflavin are little affected.

2.3 Anti-nutritional factors

According to Gupta, Barat, Wagle and Chawla (1989) anti-nutritional factors may be broadly defined as chemical components of foods, which interact with food nutrients and make them unavailable. Some of the products of such interactions may also be toxic. These authors have listed some of these factors as nitrates, trypsin inhibitor, saponins, phenols, mycotoxins, lectins and phytates. Phytic acid in cereals and aflatoxins in peanuts are of major concern.

2.3.1 Aflatoxins

The aflatoxins are the best known toxic compounds of peanuts. They are the metabolic by–products of the moulds *Aspergillus flavus* and *Aspergillus parasiticus* (Nwokolo, 1996). Chemical and physiological aspects of four distinct types of aflatoxin (i.e. B_1, B_2, G_1 and G_2) have been studied. The author reports that amongst the four, aflatoxin B_1 is the most toxic and best known because it is a very potent hepatocarcinogen. It is also reported to be mutogenic, causing chemical modifications of the DNA, inhibiting RNA synthesis and interfering with protein synthesis.

Rhee, (1985) reports that toxigenic microorganisms are ubiquitous in the environment, and mould infection of badly harvested or poorly stored peanuts, occurs around 20-25°C. Aflatoxin poisoning occurs if these mouldy peanuts are eaten or processed into food or feed.

2.3.2 Phytic acid

Phytic acid is an important constituent of cereals, legumes and oilseed crops (Kent & Evers, 1994). In the free form phytic acid is unstable, decomposing to yield

orthophosphoric acid, but it is stable in the dry salt form. The terms phytic acid, phytate and phytin refer respectively to the free acid, salt and calcium/magnesium salt. Phytate (salt form) accounts for 80% of the total phosphorus stored in many cereals and legumes. It forms insoluble complexes with minerals and this leads to reduction in their bioavialability and thus to mineral deficiencies. According to Reyden and Selvendran (1993) phytic acid molecule is a good chelator and it forms insoluble complexes with mineral cations and proteins. The complexes can form precipitates, which reduces protein digestibility.

2.4 Cereal-legume composite foods

The major objective of compositing cereals with legumes, which are slightly limiting in the sulphur-containing amino acids, cysteine and methionine, but contain sufficient lysine to overcome the lysine deficiency of cereals, is to improve its nutritional value (Wijeratne, 1992).

Cereals are the basic diets consumed by large sectors of the population living in developing countries. They are the most important sources of nutrients (Steller, 1993). The main problem with cereals is that they are starchy foods, but they can provide all nutrients essential for health if composited with legumes and other protein rich food types like milk, animal products, fruits and vegetables (Vorster & Venter, 1993). Compositing of cereals and legumes can provide essential nutrients and energy and help to prevent under-and malnutrition, which is prevalent in developing countries. Maize is rich in starch and vitamin A (yellow maize), but poor in protein, oil and vitamins (riboflavin, thiamin and niacin). Peanuts, however, are rich in proteins, oil and vitamins (riboflavin, thiamin and niacin), but poor in starch and vitamin A. Nwokolo (1996) reports that peanut protein is highly digestible and the biological value of peanut protein is among the highest of all the vegetable proteins and equals that of casein (milk protein). A combination of oil-seed (peanut) proteins, which are high in lysine, with a cereal (maize) that contains a relatively good concentration of sulphur-amino acids results in a

nutritional complementation, the protein quality of the mixture is greater than that for either protein source alone (Young & Pellet, 1994).

2.5 Food preservation

Food preservation is an umbrella term covering any measure that makes food keep well over a reasonable period (Gould, 1989). Without preservation, foods undergo deterioration to varying degrees in organoleptic properties and nutritional value. The primary objectivee of food preservation is to avoid these deteriorations of food by methods which can reduce physical, chemical and biological deterioration/spoilage (Potter, 1986).

2.5.1 Heat processing and preservation

The use of heat in food preservation finds wide application and is one of the most important methods for extending the storage life of foodstuffs (Lund, 1988). It ensures year round availability of foods and therefore, increased availability of nutrients to the consumer. However, heat processing also has a detrimental effect on nutritional quality because thermal degradation of nutrients can and does occur. Several processes involving the use of heat are currently applied to foodstuffs. Perhaps the most common of these is canning.

2.5.1.1 Canning

According to Desrosier and Desrosier (1977) Frenchman Nicholas Appert at the close of the eighteenth century invented canning. Canning is a unit operation that follows closure of the container and involves heating at a predetermined temperature/time combination. The heating medium can be either saturated steam or hot water and the process itself can be either batch or continuous (Fellows, 1990). It is a general fact that canning can effectively inactivate both bacterial vegetative cells and spores rendering the food almost permanently preserved (Gould, 1989). Because canning involves heating the product,

some other benefits realised are product softening which improves its palatability. The digestibility of the product is also improved due to destruction of anti-nutritional factors, such as trypsin inhibitors and lectins found in legumes, and also the heat modifies proteins thus improving their digestibility (Pither, 1993).

Commercial sterility means conditions achieved by application of heat which renders food free of viable forms of micro-organisms having public health significance, as well as any microorganisms of non-health significance capable of reproducing in the food under normal non-refrigerated conditions of storage and distribution (Lopez, 1987a). The recommended sterilisation processes are not designed to kill all microorganisms in canned foods and this makes canned foods to be "commercially sterile" but not bacteriologically sterile. Lopez (1987a) states that a heating process that produces commercial sterility in low acid canned foods (i.e. pH > 4.6) like *Tshidzimba* may be defined as a process whereby all pathogenic bacteria (mostly *Clostridium botulinum*) will be destroyed, as well as more heat resistant microorganisms which are capable of causing spoilage to canned foods stored under normal conditions and during distribution.

2.5.1.2 Basic considerations in establishing safe thermal processes for low-acid food Products

According to Berry (1993) foods that have a pH of greater than 4.6 and a water activity of greater than 0.85 are known as low-acid foods. This combination of pH and a_w is capable of supporting the growth of *C. botulinum,* a bacterium that produces an exotoxin which is one of the most deadly neuroparalytic toxins known. Some of the examples of low-acid foods are vegetables like legumes, cereals and their products (*Tshidzimba* and weaning foods).

Lund (1978) states that to design a thermal process in order to accomplish an activation of spores or vegetative cells, information needed is the rate of destruction of the microorganism or spore and the dependence of the rate on temperature and nature and

temperature history of the food product. Figure 2 shows the steps involved in establishing a safe thermal process.

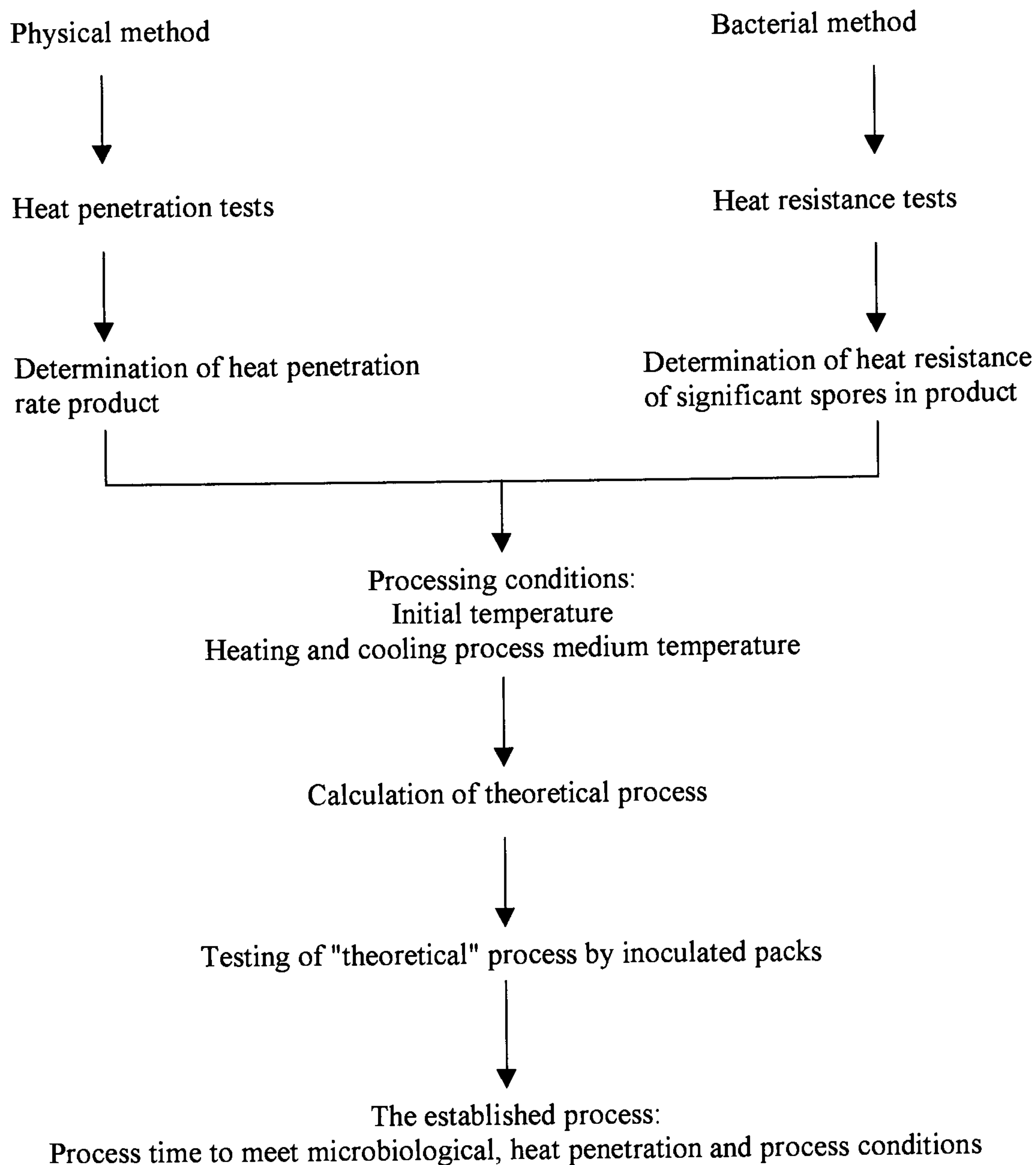

Figure 2. Pathways for development of a thermal process (Minnaar, 1993)

2.5.1.3 Thermal inactivation of micro-organisms

According to Gould (1989) the primary objective of every thermal preservation is to supply enough heat to a particular food product in order to reduce the survival chance of an organism that can grow in that food to an acceptably low level. In low acid foods like *Tshidzimba* this is based on *C. botulinum*. Brown (1991) states that the minimum thermal processing for a low acid canned food must reduce the probability of survival of *C. botulinum* spores to less than 1 in 10^{12} containers. It is believed that a sterilisation technique that can destroy *C. botulinum* will leave the food product free of spoilage organisms because *C. botulinum* is regarded as highly heat resistant (Lopez, 1987b). Apart from destroying spoilage and pathogenic microoganisms, heat also inactivates enzymes endogenous to the food, which could potentially cause its spoilage.

Lund (1978) reports that a shelf-stable and safe food product can be achieved through heat processing by considering standards such as the D-value, 12-D concept, z-value and F_o-value. These standards define the temperature/time combination of heat necessary to achieve a shelf-stable and microbiologically safe food product.

The D-value is the time in minutes at a given temperature to reduce the population of microorganisms or spores by 90% (10-fold or one $\log_{10}$ decrease) (Gould, 1989) as shown in Figure 3.

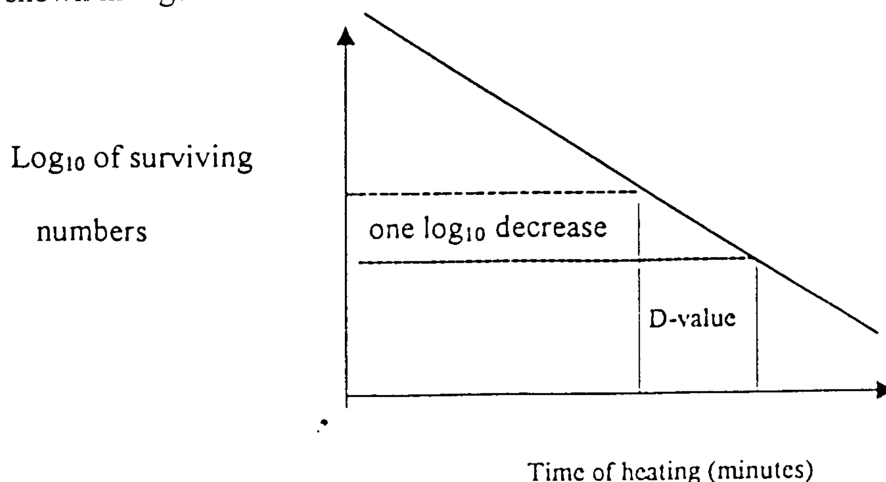

Figure 3: The D-value concept (Gould, 1989)

The 12-D concept refers to the lethality requirement to reduce the probability of survival of the most resistant *C. botulinum* spore to 10^{-12} (Berry, 1993).

The z-value (Figure 4) refers to the degrees required for the thermal destruction curve to transverse one log cycle (Berry, 1993).

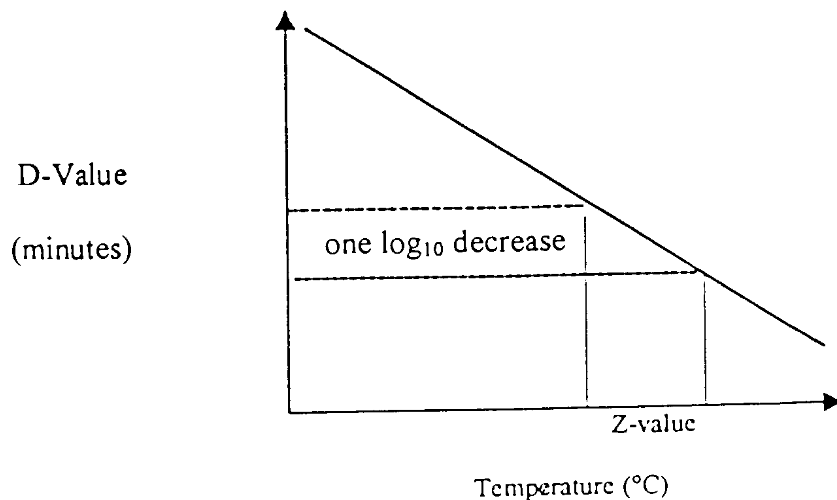

Figure 4: The z-value concept (Berry, 1993)

The F-value refers to the equivalent time, in minutes, at 121°C of all heat considered with respect to its capacity to destroy spores or vegetative cells of a particular organism, and the integrated lethal value of heat received by all points in a container during processing is designated F_0 (Jay, 1998).

F_0 is the time in minutes required to destroy a specified number of spores at 121.1°C when the z-value equals to 10°C (F_0 is in fact $F_{10}^{121.1}$). The minimum heat-treatment of low-acid food products is 115°-121.1°C for 3 min, this can reduce the available microorganisms by 12 decimals. But it is necessary to usually apply heat treatments in excess of F_0 3 (e.g. 6-7 or more) to ensure control of other spoilage organisms which can be more heat resistant than *C. botulinum* (Brown, 1991). Table 6 shows the empirical F_0–values for low-acid canned foods.

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Table 6: Empirical F_0-values for [illegible] commercially [illegible] processed food products (Pflug, 1987 according to Minnaar, 1993)

Hazard	F_0 (min)
1. Public health	
C. botulinum	3
2. Spoilage	
Mesophilic spores	
C. sporogenes; C. pasteurianum; C. butyricum;	5
C. perfrigens; C. bifermentants	
Thermophilic spores	
B. stearothermophilis; C. thermosaccharolyticum;	
Desulfotomaculum nigrificans;	
B. coagulans	
Warehouse and distribution	
mid-temperature area (< 30 °C)	5-7
Warehouse and distribution	
High-temperature area (50-60 °C)	12-21

The time required for sterilisation can be obtained by applying the following equation:

$t = D (\log_{10} x - \log_{10} y)$ (Fellows, 1990),

Where x is the initial amount of spores and y is the final amount of spores. If a can contains one spore of *C. botulinum* with a $D_{121.1°C}$ value of 0.21 min. and subjected to a 12-D process at 121.1°C, then the time is equal to

$t = 0.21 (\log_{10} 1 - \log_{10} 10^{12})$

$= 2.52$ min. (Jay, 1998)

The mechanism of heat penetration in cans is either through conduction and convection heating or combination thereof (Desrosier & Desrosier, 1977). Convection is applied on fluid food products, while conduction is used in very viscous liquid-solid foods (e.g. *Tshidzimba*) and solidly packed food material. A combination is used in food particle suspended in a viscous liquid.

According to Lund (1978) heat penetration into food products in containers depends on the following factors, surface heat transfer coefficient; physical and thermal properties of the product; difference between steam temperature and initial product temperature; container size and heat transfer type in the container (convection or conduction).

2.5.2 Effects of thermal preservation

Thermal preservation causes physical and chemical changes to foods (Pither, 1993). These changes can be desirable or undesirable and are influenced by time and temperature of the process. They also determine the product quality in terms of its organoleptic properties and nutrient content. During storage some changes do occur but they are slow and seem to have no significant effect on quality of thermally processed food products.

2.5.2.1 Effects of thermal preservation on the sensory quality of foods

Heat preservation adversely affects the sensory quality (i.e. flavour, colour and texture) of food. Table 7 shows the types of changes that take place during thermal processing. These changes may be in the form of either direct effects of heat on food constituents (e.g. starch gelatinisation, protein denaturation and cell separation), or heat induced reactions such as Maillard reaction (Pither, 1993).

Table 7. The effect of heat processing on sensory quality (Pither, 1993)

Chemical or physical reactions or changes occurring	Impact on sensory attribute
Texture	
Cell membrane damage	Loss of crispness
Cell separation	Loss of firmness
Protein denaturation	Gelling, firming
Starch gelatinisation	Gelling
Colour	
Natural pigment breakdown	Bleaching
Maillard reactions	Browning
Flavour	
Basic flavour	Stale
Volatile loss (scalping oxidation)	Loss of flavour
Volatile formation due to	
Maillard reaction	Roasted flavour, bitter
Oxidation reaction	Rancidity

2.5.2.2 Effects of thermal preservation on the nutritional quality of foods.

Hall and Pither (1991) state that nutritive value of heat preserved foods can be influenced by the chemical and physical reactions, which occur during processing. Chemical reactions include heat damage to labile nutrients such as vitamins. Other reactions that occur on canning affect the availability of nutrients within the foodstuff and, therefore, their usefulness to the body. The discussion below is of the effects of heat preservation on major nutrients.

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In general, the effects of canning on carbohydrates are directly related to their interaction with other food constituents and to the overall eating quality of the foodstuff, but not to their nutritional value.

Desrosier and Desrosier (1977) report that prolonged heating at high temperatures degrade sugars and starches. Reducing sugars are lost during Maillard reaction through their interactions with proteins. Starch granules gelatinise during heating and this improves the texture, thereby, palatability of the food. Gelatinisation also helps digestibility of the food to an extent that many foods (e.g. rice) are largely indigestible in the raw state.

Heating as in canning can disrupt cellulose the main constituent of dietary fibre, hemicellulose and pectins because these components are responsible for texture and structure in plant foods. Their disruption leads to food softening and increased palatability (Hall & Pither, 1991).

According to Pither (1993) denaturation, rupturing of the hydrogen bonds and other noncovalent bonds that can lead to changes in the conformation of the protein, can be caused by heating of proteins as in canning. The degree of denaturation depends on the level of heat treatment applied, but it can also be caused by reaction with other food constituents like reducing sugars. Generally the total level of crude protein is unaffected by canning but both desirable and undesirable changes can occur in its nutritive quality and availability. The author reports that severe heating can result to Maillard reaction as in canning of vegetables. These reactions take place between lysine and reducing and cause a reduction in availability of lysine, due to cross-linking. The same reactions can be expected to occur in canning of legumes and oil-seeds because they contain lysine and also have some reducing sugars. In legumes, canning improves their digestibility, by unfolding of the major seed globulins, as well as increasing nutritional availability, especially of the sulphur-containing amino acids, by inactivation of trypsin inhibitors (Pither, 1993).

According to Pither (1993) normal heat processing does not alter the nutritive value of the fat content of foods significantly. However, hydrolysis reactions that result in separation of fatty acids from the glycerol unit may occur, but the reactions have less effect on nutritional value of the fat as the resulting free fatty acids are available for digestion.

In general, the canning process does not adversely affect total mineral levels because they are relatively stable under conditions of heat, acid or alkali (Hall & Pither, 1991). But due to their interactions with other food components, they are susceptible to changes in bioavailability. The bioavailability of iron can be enhanced during canning in the presence of reducing sugars with which it forms available complexes.

Hall and Pither (1991) report that most vitamins are unstable under heat conditions and this makes them to be susceptible to losses during the canning process. In general, fat-soluble vitamins are more heat-stable than the water-soluble vitamins. Thiamin (water-soluble) is the most heat-sensitive of the B vitamin and its loss in canning can be substantial. Peas may lose 50% of their thiamin during canning preservation. Losses of as high as 80% were also reported in canned Lima beans and maize.

Though fat-soluble vitamins are more stable to heating than water-soluble, losses occur during canning as a result of oxidation (Hall & Pither, 1991). With vitamin A chemical oxidative reactions promoted by heat and metals such as copper are responsible for its degradation (Imungi, 1996). But losses in vitamin A can be avoided or reduced if air is excluded and moderate temperatures are used during heating, because at high temperatures long polyunsaturated carbons of carotenoids undergo isomerisation from the *trans* to the *cis* form and therefore lose the vitamin activity (Pither, 1993, Imungi, 1996).

2.5.3 Drying

According to Jay (1998) food preservation by drying is based on the fact that microorganisms, enzymes and chemical reactions need water in order to be active. It is

the availability of water for microbial, enzymatic or chemical activity that determines the shelf-life of a food, and this is measured by the water activity of food. Water activity (a_w) is defined as the vapour pressure of water in a food product compared with the vapour pressure of pure water at the same temperature (Chirife & Del Pilar Buera, 1994). In order to preserve foods by drying, one needs to lower the a_w to a point where the activities of food-spoilage and food poisoning microorganisms are inhibited.

Barnwart (1989) and Jay (1998) report that a_w is widely used as a determinant of physiological activity. Almost all microbial activities are inhibited below $a_w = 0.6$, most fungi are inhibited below $a_w = 0.7$, most yeasts are inhibited below $a_w = 0.8$ and most bacteria below $a_w = 0.9$. Biochemical and non-biological chemical reactions are influenced by a_w since free water acts as a solvent for the reactions. Reducing a_w is a powerful food preservation technique and drying is one of the methods that reduce the a_w of food. In *Tshidzimba* the main microorganisms responsible for spoilage are coliforms, yeasts and moulds. Therefore, reducing the a_w of *Tshidzimba* to 0.5 can inhibit their activities. Desrosier & Desrosier (1977) indicate that dried foods because of the removal of moisture are more concentrated than any other preserved form of foodstuffs. Compared to other preserved foods, they are less costly to produce because labour requirement is at its minimum. They also need minimum storage requirements.

2.5.3.1 Mechanism of drying

Fellows (1990) reports that during drying hot air conveys heat to the food, causing water to vapourise and it is the vehicle to transport the liberated water vapour from the dehydrating food (Figure 5). A lower water vapour pressure region is created at the surface of food because of this, while a water vapour pressure gradient is established from the moist interior of the food to the dry air. The established water vapour pressure gradient supplies the driving force for moisture removal from the interior of the food. Moisture follows the following mechanism to move to the surface of food: movement of liquid through capillary forces; the diffusion of liquids due to differences in the concentration of solutes in different regions of the food; the liquids which are adsorbed in

layer at the surface of solid components of the food will also diffuse and finally diffusion of water vapour in air space within the food due to vapour pressure gradient.

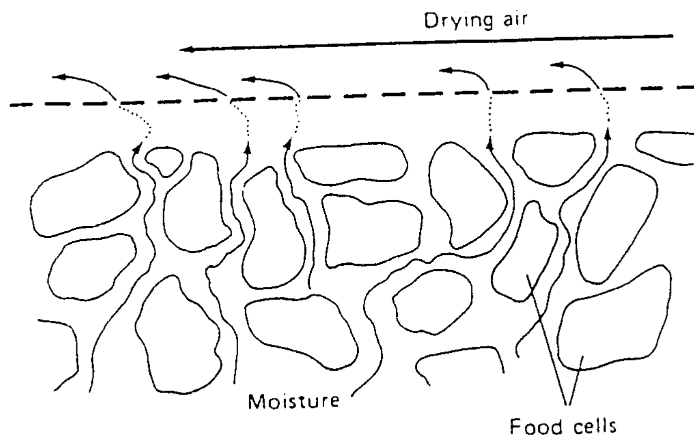

Figure 5: Movement of moisture during drying (Fellows, 1990)

2.5.3.2 Methods of drying

According to Chung and Chang (1982) several types of drying methods have been developed in order to meet dehydration characteristics of specific food products, because of complexity and diversity of food products. The method of choice depends upon the type of food to be dried, the quality level that must be achieved and the cost that can be justified.

Sun drying is the most used and economical kind of drying in the world. Desrosier and Desrosier (1977) state that almost all the cereals are preserved by drying and with sun drying playing a major role. There are some sophisticated drying methods developed from sun drying like solar drying (Banaparte & Raghaven, 1998). In solar drying, solar energy is collected and used to heat air, which in turn is used for drying.

According to Jelen (1985) the principle of sun drying is that heat energy from the sun evaporates the water from food to surrounding environment or air. Sun drying unlike other drying methods has several disadvantages. It is dependent upon the element (sun), it is slow and not suitable for many high-quality products, it can not lower moisture content below about 15% which is too high for storage stability of numerous food products, it needs considerable space, and the food being exposed is subject to contamination and losses from dust and insects (Potter, 1986).

According to Jelen (1985) the principle of hot air drying is that a stream of hot air in a closed environment supplies the heat by convection and carried away the evaporated water. Theoretically all water vapourisation occurs on the food's surface, thus protecting the food interior damage during hot air drying. This is not always the case in practical drying operations, severe heat effects like browning, heating flavours, denaturation of proteins and other effects resulting in loss of solubility upon dehydration, texture changes and some nutrient losses in heat labile vitamins can be encountered.

Hot air drying due to its hygienic advantages over sun drying has been recommended for drying of pastes and porridges (Griffith, Castell-Perez & Griffith, 1998), and therefore may be used for *Tshidzimba*.

According to Kimmons, Brown, Lartey, Collison, Mensah and Dewey (1999) drum dryers are the single most widely used type of dryer for drying of porridges and pastes. Drum dryers are slowly rotating hollow steel drums, which are heated with steam. Food in the form of slurry is heated on the surface of the drum. Drum dryers have high drying rates and high-energy efficiencies. However, they require high capital, and high temperatures used causes heat damage to sensitive foods. However, drum drying is useful in preserving starchy foods such as pre-cooked cereal foods (Fellows, 1990), because starch is less sensitive to heat damage.

2.5.3.3 Influence of drying on microorganisms

Desrosier and Desrosier (1977) report that microorganisms are widely distributed throughout nature, and the fact that foodstuffs at one time or another are in contact with soil and dust, it is anticipated that microorganisms will be active whenever conditions permit. The process of drying is not lethal per se to microorganisms and because of this many types of microorganisms may be recovered from dried foods, especially if poor-quality foods are used for drying and if improper practices are not followed in the drying steps (Jay, 1998)

According to Barnwart (1989) if drying proceeds at a slow rate and at acceptable temperature, the microorganisms may multiply during the process. To avoid multiplication of microorganisms during the drying process food should be dried either at a higher or low temperature, so that bacterial growth cannot occur until the water content is reduced to a level that will inhibit microbial action. But one must bear in mind that even though the viable microbial load is decreased during drying, the dried product is not sterile. According to Desrosier and Desrosier (1977) the moisture level in food determines which microorganisms will have an opportunity to grow.

Jay (1998) reports that moisture removal like in drying lowers the a_w, resulting in the selective growth of microorganisms. Different microorganisms have specific tolerances to reduced a_w. Usually, the dried product has a lower microbial level than the original food due to the inactivation of microorganisms. Of those organisms that survived drying, some have been stressed and have sublethal lesions (Desrosier & Desrosier, 1977). This is influenced by the organism (species, strain, physiological age, state of the cell, cell concentration), the condition of drying (spray, moisture, temperature, time, the rate and extent of water loss), and the type of food or suspending medium (protective factors, pH, inhibitors) (Jay, 1998).

2.5.3.4 Effects of drying on food

Application of heat (e.g. hot air drying) to food is probably the cheapest dehydration process compared to freeze drying and others, but suffers serious disadvantages that include loss of volatiles and flavours, changes in colour and texture, and a decrease in nutritional value (Nijhuis, Torringa, Muresan, Yuksel, Leguijt & Kloek, 1998).

Dried foods quality deterioration is mainly caused by textural changes (Fellows, 1990). With reconstituted product the size and extent of size reduction during drying affects its texture. While bulk density and the ease with which the powders are reconstituted contribute to textural changes in powders. All these properties are determined by the composition of food, method of drying and particle size of the product.

Dried food products experience flavour loss due to loss of volatile components from the food during drying and oxidation of pigments, vitamins and lipids during storage (Fellows, 1990). The extent of volatile loss is temperature, solids concentration of the food, the vapour pressure of the volatiles and their solubility in water vapour dependent. Different volatiles are lost at different drying stages, for example at an early stage of drying volatiles which have a high relative volatility and diffusivity are lost and fewer volatile components are lost at a later stage. These losses can be minimised by controlling drying conditions during each stage of drying. In the case of aroma loss due to oxidation, storage temperature and a_w of food determine the rate of deterioration (Desrosier and Desrosier, 1977).

Desrosier and Desrosier (1977) report that drying of food causes changes in the surface characteristics of food and hence alter the reflectivity and colour. Heat and oxidation were also found to cause chemical changes to carotenoids during drying. According to Fellows (1990) prolonged drying times and higher drying temperatures generally produce greater pigment losses. Caramelisation and Maillard reaction are also likely to occur in substances with high carbohydrate and protein concentrations like cereal/legume composites during heating.

Food losses its moisture contents during drying, and this results in increasing the concentration of nutrients in the remaining mass (Desrosier & Desrosier, 1977). Major nutrients like protein; carbohydrates and lipids are available in larger amounts per unit weight in dried foods compared to their fresh counterparts. There is a loss in vitamin content mostly with water-soluble vitamins, but the loss rarely exceeds 5-10%. With proteins, their biological value depends on the method of drying. Prolonged exposures to high temperatures can render them less useful in the dietary, while low temperature treatments increase their digestibility over native material. Fats undergo rancidity during drying and at higher temperatures their oxidation increases also.

2.5.4 Fermentation

Gibson (1995) defines fermentation as the process by which microorganisms propagate themselves utilising their external medium as a source of nutrients. During fermentation, the presence of fermentive microbes like lactic acid bacteria causes acidification of the food and production of bacteriocins (Gibbs, 1987). As the tolerance of microorganisms to widely differing pH levels varies naturally, the pH selects the species or group of fermentive microorganisms that will predominate in unaltered food products.

Fermentations by fermenting microorganisms like lactic acid bacteria generally provide a form of bio-control by inhibiting the growth of undesirable spoilage and pathogenic organisms, thus preserving the products (Smith & Palumbo, 1981). Due to this form of bio-control which fermentation provides, it is considered to be a relatively safe form of food preservation and the products are not commonly associated with food poisoning outbreaks (Dillon & Cook, 1994). The preservative effect in fermentation process is not only due to the increased concentration of the undissociated acids and the concomitant decrease in available fermentable carbohydrates but also depends on a series of interacting mechanisms (Daeschel, 1989).

When preserving food through fermentation the key factor is that the fermentive microbes must have the ability to reproduce faster than the competing microbes for

example the pathogenic or spoilage bacteria under the imposed storage conditions (Dillon & Cook, 1994). This can be achieved by interplay of factors like depletion of nutrients, exclusion of oxygen and lowered a_w. According to Daeschel (1989) the fermenting microorganisms produce hydrogen peroxide (H_2O_2), ethanol, diacetyl and bacteriocins in addition to organic acids.

2.5.4.1 Benefits of fermentation

According to Nout (1994) fermentation plays five roles:
1) Enrichment of the human dietary through development of a wide diversity of flavours, aromas and textures in food; 2) preservation of substantial amounts of food through lactic acid, alcoholic, acetic acid and alkaline fermentations; 3) enrichment of food substrates biologically with protein, essential amino acids, essential fatty acids and vitamins; 4) detoxification during food fermentation processing and 5) a decrease in cooking times and fuel requirements.

2.5.4.2 Lactic acid fermentation

Lactic acid bacteria are mostly the predominant microorganism and main producers of the acid and flavour compounds in many cereal fermentations (Halm, Lillies, Sorensen & Jakobsen, 1993). The dominant lactic acid bacteria in traditional *Kunun gyada*, a weaning porridge similar in composition to *Tshidzimba* are *Lactobacillus plantarum* and *L. lactis* (Nkama, Ilias & Jato, 1995). In *uji*, a related fermented maize porridge from Kenya, the dominant lactic acid bacteria is also *L. plantarum*. Other lactic acid bacteria involved in this fermentation are *L. cellobiosus, L. bucchneri, L. fermentum, Pediococcus acidilactici and Pediococcus pentosaceus* (Mbugua, 1984). In *Mawe*, a fermented maize dough from Benin, *Lactobacillus* species constituted the majority of the lactic acid bacteria while *L. fermentum* and *L. reuteri* dominated the final stages of the fermentation (Rombouts, Nout, Houghoulgan, Nago & Houben, 1993). *S. lactis* and *Lactobacillus* species are the predominant lactic acid bacteria in *Togwa*, a Tanzanian fermented maize gruel. Cook (1993) reports that fermentations involving lactic acid bacteria have potential for more

wide spread applications, particularly for the preservation of cereals and legumes to provide safe, low-cost weaning foods for developing countries. Lactic acid bacteria found in fermented foods are a rich source of antimicrobial compounds including organic acids, diacetyl, acetoin, hydrogen peroxide and bacteriocins. Nisin, a bacteriocin produced by *Lactococcus lactis* spp. *Lactis*, is active against some bacteria, has GRAS (generally regarded as safe) status and is now approved for use as a preservative in more than 40 countries.

Lactic acid bacteria are collectively assigned to the family *Lactobacteriaceae* (Holt, Krieg, Sneath, Staley & Williams, 1984). This family is composed of the genera *Lactobacillus*, *Leuconostoc*, *Pediococcus*, *Lactococcus* and *Streptococcus*. They are morphologically heterogenous, including long and short rods as well as cocc*i*. All members of *Lactobacteriaceae* are Gram positive, do not form spores (except *Sporolactobacillus inulinus*) and are non-motile (Schlegel, 1986). Lactic acid bacteria depend on carbohydrates for their energy supply and produce lactic acid. They are obligate fermenters and do not contain catalase enzyme. Although they are anaerobic, they are aero-tolerant and are at times referred to as micro-aerophilic. An aerobically growing, Gram positive bacterium that does not produce catalase is thus regarded as lactic acid bacterium (Schlegel, 1986).

Gibson (1995) reports that for a fermentation process to be successful, the medium in which the microorganisms will grow must provide essential nutrients (e.g. vitamins, amino acids, purines and pyrimidines) and the correct environment to promote respiration and growth.

Lactic acid bacteria can easily dominate in an appropriate environment. They can be isolated by enrichment on selective or elective media (Schlegel, 1986). Although lactic acid bacteria are acid tolerant, this property is not unlimited. Therefore, because of the large amounts of lactic acid produced, the media must be well buffered; especially when pure cultures are to be maintained (Kandler & Weiss, 1986).

Based on their temperature requirements, the lactic acid involved in the various food fermentations are divided into two general categories, namely:

- Mesophilic organisms with optimum growth temperature of 30° to 34°C, and these include the genera *Lactococcus* and *Leuconostoc*.
- Thermophilic organisms with optimum growth temperature of 35° to 40°C. These include the genera *Lactobacilus* and *Stretococcus* (Schlegel, 1986).

Kandler and Weiss (1986) state that, lactic acid bacteria may be called hetero-fermentative or homo-fermentative depending on the pathways they use to metabolise glucose. Lactic acid bacteria that produce more than 90% lactic acid are called homo-fermentative while those that produce gases and other organic acids in addition to lactic acid are called hetero-fermentative.

2.5.4.3 Effects of fermentation on food

Apart from preserving different food types, fermentation is responsible for sensory and nutritional characteristics of different foods. The effects of fermentation on the organoleptic properties and main nutrient groups are hereby discussed.

Fermentation can results in new or improved flavours, aroma and texture (Cook, 1993). Fermented foods often have distinct organoleptic properties compared to unfermented products. Aroma and flavour compounds of fermented foods may include acids, carbonyl compounds, esters, ethanol, fusel oils, ketones, lactones and pyrazines. Both texture and organoleptic properties may be altered; for example cereals into bread and soya beans into soy sauce or Indonesian *Tempe* (moulded soya bean cake)

Fermentative action of microbes brings about a significant nutritional enrichment and this includes increases in protein levels (particularly amino acids) or vitamins (Cook, 1993). The author indicates that fermentation can increase the protein content of high-starch substrates, such as polished rice, like in Indonesian *Tape* fermentation of glutinous rice. Fermentation also causes loss of starch solids and this leads to a doubling of protein content on a dry mass basis. The sulphur-containing amino acids are often limiting in

legumes, and rice and wheat may be deficient in lysine. Levels of methionine increased during *Tempe* and Indian *Idli* fermentations, while Indonesian *Tape* and wheat/soya bean *Tempe* fermentations reportedly increased lysine content. Fermentations of cereal/legume composites are particularly important nutritionally because the balance of amino acids is often improved, and a higher protein efficiency ratio (PER) can also be achieved through fermentation.

Fermentation can lead to nutritional improvements in some vitamins like in the sorghum and maize beer fermentations of Southern Africa, the increase in levels of thiamin in Indonesian *Tape* fermentation of rice and vitamin B_{12} in Korean *Kimchi* vegetable fermentation and Indonesian soya bean *Tempe* fermentation (Cook, 1993). These increases in vitamins are of greater importance to people who consume a limited diet.

Nout and Rombouts (1992) state that most fermented foods provide a valuable source of readily available energy, including glucose, maltose, ethanol and organic acids. Fermentation may also lead to a nutritionally more favourable balance of fatty acids, with increases in levels of polyunsaturated acids.

2.5.4.4 Back slopping

In order to accelerate the fermentation and its predictability, process control is required. This can be achieved through ecological or environmental control. According to Nout & Rombouts (1992), ecological control involves the enrichment of starter organisms in food by natural selection. Recycling part of the previous fermented product (also called back-slopping) (Holzapfel, 1989) results in a highly competitive and well adapted multiple strain starter culture. Environmental control involves the fermentation to ensure and maintain the dominance of starter organisms over epiphytic micro-flora.

Usually 5 to 10% of the previous fermented product is used for back-slopping. According to Nout, De Dreu, Zuubier and Bonants Van Laarhoven (1987), this results in improved and predictable acidification and in general a fermentation process that can be better

controlled. The acidification process stabilises within three to five consecutive fermentation cycles (Nout, 1994). This in turn improves the quality and safety as well as increasing the shelf life of the final product.

2.6 SUMMARY

Some research has been done on drying and fermentation preservation of foods of grain origin such as maize, millet, soybean, cowpeas, groundnuts and the influence of these preservation treatments on protein quality. Although there has been some research reported on preservation of composites (cereal-legume) using fermentation and drying techniques. It is also clear that little work has been reported on the preservation of cereal-legume composites through canning for example the canning of Chilean *Humitas* maize-sweet lupin composite and nothing about canning of maize and peanut composite porridges. It was therefore decided to devise this project to help develop the required know-how.

2.7 Objectives

The objectives of this investigation were as follows:

- To establish a standard procedure for the preparation of *Tshidzimba*.
- To determine whether canning, drying and fermentation can be used to extend the shelf-life of *Tshidzimba*.
- To determine the effect of canning, drying and fermentation on the quality of *Tshidzimba*.

3. MATERIALS AND METHODS

3.1 Materials

White maize samp and whole peanuts were purchased from Pick 'n Pay supermarket, Hatfield, Pretoria. The materials were stored at 14°C and relative humidity of 80%. All experiments were done in duplicate.

3.2 Experimental design

A simplified flow diagram of *Tshidzimba* preparation and preservation is given in Figure 6.

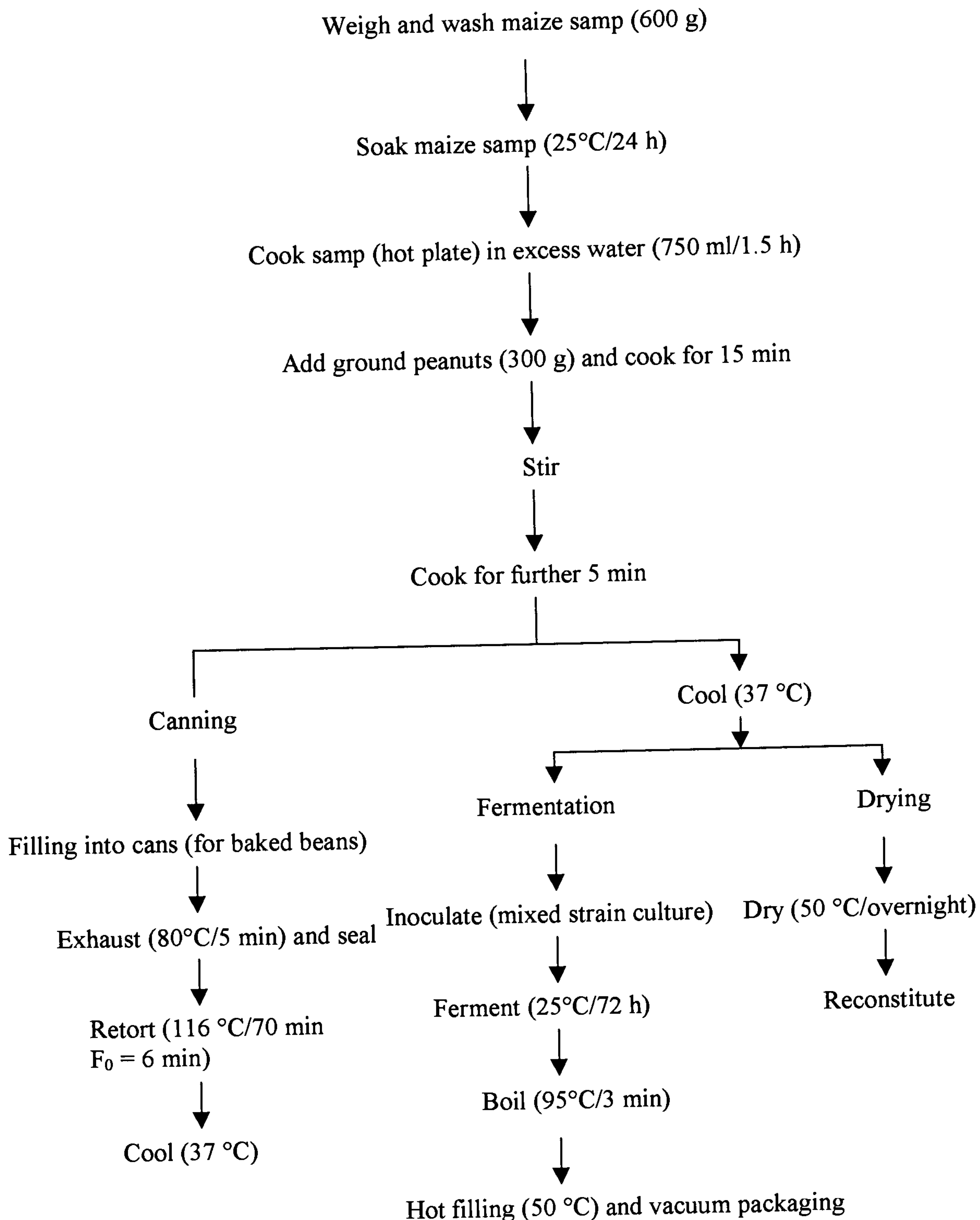

Figure 6. Flow diagram of preparation and preservation of *Tshidzimba* porridge stored for 21 days at 25°C

3.3 Methods of preservation

3.3.1 Fermentation

White maize flour (50 g) was weighed into plastic container (500 ml) and 64 ml tap water was added. The resulting slurry was well mixed and then closed with the lid of the container. The container was then placed in a 25°C incubator. The pH of the culture was monitored daily. When the pH fell to 3.6, the culture was thoroughly mixed and 20 ml transferred into a clean plastic container, containing maize flour (50 g). Warm (approx. 30°C) tap water (64 ml) was added and the slurry mixed. The container was closed and returned to the 25°C incubator. This transfer procedure was repeated weekly.

Tshidzimba was prepared and mixed thoroughly with the maize inoculum. The mixture was fermented in a temperature-controlled incubator at 25°C for 72 h until a pH of 3.9. Duplicate samples of the mixture were taken each day for pH and titratable acidity measurements. After the 72 h fermentation period, the fermented *Tshidzimba* was transferred into a stainless steel pan and boiled for 3 min at 95 ± 2°C to stop the fermentation process. The boiled fermented *Tshidzimba* was hot filled and vacuum packaged in vacuum plastic bags.

3.3.2 Drying

Tshidzimba was cooked as shown in Figure 6 and put in a forced-draught oven at a temperature of 50°C overnight. The final product was in a flake-form and it was packaged in vacuum plastic bags under normal conditions (not vacuum).

3.3.3 Canning

Tshidzimba was cooked and 350 g of the product was filled into baked beans cans (length-110mm; diameter-78mm). The cans were exhausted at 80°C for 5 min and sealed. The sealed cans were put into a retort and retorted at 116°C for 70 min at $F_o = 6$ min. The cans were then cooled in the retort, labelled and stored at ambient temperature.

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Figure 7. Fermented, dried, canned and fresh (unpreserved) *Tshidzimba*

3.4 Chemical analyses

The following chemical tests were carried out on the unpreserved, canned, dried and fermented *Tshidzimba*. The chemical determinations were done in triplicate.

3.4.1 Moisture

The moisture content was determined following the AOAC official method 925.10 (air oven method) (Association of Official Analytical Chemists, 1995a). Approximately 2 g of *Tshidzimba* (unpreserved, canned, dried and fermented) was accurately weighed into previously dried (in a forced draught oven at 105°C for 1 h), cooled and weighed moisture tins. The samples were then dried for 3 h in a forced draught oven at 105°C. The dried samples were cooled in a dessicator and weighed. Loss in weight was reported as moisture using the formula below.

$$\%\text{ moisture} = 100 - \left[\frac{(\text{mass dried sample} + \text{tin}) - (\text{mass empty tin})}{\text{mass of sample}} \times \frac{100}{1}\right]$$

3.4.2 Protein

Protein coontent (N x 6.25) was determined by the Kjeldahl method, as modified in AOAC Method 2.057 (Association of Official Analytical Chemists, 1980) using a Büchi 322 Distillation Unit and Büchi 430 Digester.

3.4.3 Fat

AACC method 30-20 (Soxhlet extraction) (American Association of Cereal Chemists, 1983) was used to determine fat. The principle of the method is that petroleum ether dissolves (extraction) all the lipid material in the sample and then evaporated over a boiling water bath. Leaving the lipid material as a sediment in the container and the

amount of lipid (fat) extracted is calculated by mass difference. The following formula was used to calculate fat:

$$\% \text{ fat} = \frac{(\text{mass beaker} + \text{fat}) - (\text{mass beaker})}{\text{mass of sample}} \times \frac{100}{1}$$

3.4.4 Amino acids

The Pico.Tag-method (Cohen & Tarvin, 1984) was used to determine the composition of amino acid. The method involves three steps:

1. Hydrolysis of the protein or peptide sample to yield free amino acids.
2. Pre-column derivatization of the sample.
3. Analysis by reverse phase HPLC.

In the pre-column steps, protein and peptide samples are first hydrolysed with HCl, then derivatized with phenylisothiocyanate (PITC) to produce phenylthiocarbamyl (PTC) amino acids. These amino acid derivatives may then be analysed by HPLC in amounts as low as 1 picomole.

3.4.5 Ash

Determination of ash was done according to AOAC official method 923.03 (Association of Official Analytical Chemists, 1995 b). The principle of the method is that combustion at 550°C converts all the organic matter in the sample into gaseous carbon and the mineral sediment on the dishes. The mineral content (ash) is then calculated by mass difference.

Approx. 3 g sample was weighed accurately into an ashing that had been previously ignited, cooled in a dessicator and weighed. The samples were combusted in a furnace at approx. 550°C for 6 h. The samples were then cooled in a dessicator, and the resulting light grey ash was weighed.

Ash content was calculated using the following formula:

$$\% \text{ Ash} = \frac{(\text{mass of crucible} + \text{ash}) - (\text{mass of empty crucible})}{\text{mass of sample}} \times \frac{100}{1}$$

3.4.6 Titratable acidity

Titratable acidity is expressed as millilitres of 1 M sodium hydroxide (NaOH) required to raise the pH of 100 g of the test substance to pH 6.3.The pH meter was standardised and calibrated with pH 7.00 and pH 4.00 standard buffers. Hand burette (25 ml) was checked (particularly operation of tap) and filled with 0.5 M NaOH. The test sample was attemperated to the sample temperature at which the pH meter was standardised. Approx. 50 g of well-mixed sample was accurately weighed into a 100 ml beaker, with the aid of the 10 ml pipette. The rinsed electrode was inserted into the sample and the pH was determined and recorded to the nearest 0.01 pH while stirring. NaOH was added in portions of about 1.5 ml up to pH 5.6 then in smaller increment of about 0.15 until exactly pH 6.3 was reached. Then the millilitres were recorded to the nearest 0.1 ml of 0.5 M NaOH required to raise the pH of the sample to 6.3.

3.4.7 pH

The pH was measured using a glass electrode connected to a standard pH-meter PHM82 (Radiometer, Copenhagen, Denmark).

3.4.8 Water activity

Water activity is the ratio of vapour pressure of the solution to the vapour pressure of pure water at the same temperature. The water activity of the sample was determined using a water activity meter (Novasina Thermoconstater, Zurich, Switzerland). Approx. 3 g of the sample was placed in the a_w meter at constant temperature (25°C) and a relatively humidity sensor was used to measure the relative humidity (RH). The unpreserved,

canned and fermented samples were placed in the meter for 8 h and the dried sample for 5 h. Water activity was calculated as follows:

$$a_w = \frac{\text{Equilibrium Relative Humidity}}{100}$$

3.5 Microbiological analyses

The following microbiological tests were carried out: Total plate count, coliforms, anaerobic spores, yeasts and moulds. The tests were done to determine the shelf life of unpreserved *Tshidzimba* and to establish the effect of canning, drying and fermentation on the microbiological quality of *Tshidzimba*.

3.5.1 Total plate counts

The total plate count was done according to the method of Refai (1979). Total plate count agar (23 g) was mixed with 1 l of distilled water. The mixture was sterilised at 121°C for 15 min. The agar was cooled and kept in a water bath at 45°C. The buffered peptone water (BPW) was prepared from 1 g of peptone, 5 g of NaCl and distilled water. The buffer was then autoclaved at 121°C for 15 min.

Approx. 10 g of the sample was put in a sterile stomacher bag and 90 ml of BPW was added to the sample. The mixture was blended in a stomacher for `1 min. The serial dilutions of 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} were made, by taking a 1ml of the homogenate and pipetting it into 9 ml blank peptone solution and was mixed thoroughly to give a 10^{-2} dilution. From the 10^{-2} dilution 1 ml of the dilution was transferred into another 9 ml blank peptone and mixed thoroughly. The same procedure was repeated until the 10^{-5} dilution was reached.

From each prepared dilution, 1 ml was pipetted into sterile plastic petri dishes in duplicate and 20 ml of the total plate at 45°C was poured into the dishes. The dishes were

swirled gently to mix the agar with the dilution. The agar was left to solidify at room temperature (25°C) for 15 min. The petri dishes were inverted and incubated at 30°C for 72 h.

Only the plates with colonies between 30-300 were counted from the duplicates. Mean of the colonies from each duplicate was calculated.

3.5.2 Coliforms

Using the Violet Red Bile Agar (VRB), following the Refai (1979) method tested for the coliforms. VRB agar (39 g) was mixed with 1 l of distilled water. The mixture was autoclaved at 121°C for 15 min. The agar cooled and kept in a water bath at 45°C. The serial dilution pour plating and colony enumeration were carried out as 3.4.1 respectively. The dishes were incubated at 25°C for 24 h.

3.5.3 Yeasts and moulds

For the yeasts and moulds determination, potato dextrose agar (PDA) was used (Refai, 1979). Potato dextrose agar (PDA) (39 g) was mixed with 1 l of distilled water. The mix was autoclaved at 121°C for 15 min. After sterilising the agar was kept in a water bath at 45°C and 10% tartaric acid was added to lower the pH to 5.8 ± 0.2. The enumeration of colonies was done in the same manner as 3.4.1 respectively. The dishes were incubated at 25°C for 72 h.

3.5.4 Anaerobic spores

Anaerobic spore counts were done following the most probable number technique of the International Dairy Federation (IDF, 1985). Tubes were incubated anaerobically. The freshly sterilised culture medium (TPGYT broth) (Biolab) was cooled down to ≈50°C and inoculated with at least 1 ml of three successive dilutions of the sample using three tubes for each dilution. After inoculation 2 ml of sterile thioglycollate agar (Merck) was

added to each tube so that it formed a seal of at least 10 ml on top of the medium so as to maintain anaerobic conditions. The tubes were then incubated at 37°C for 7-14 days, but inspected daily for signs of gas production and marking all tubes in which gas was produced. If more than one dilution had all its tubes positive, the highest dilution with all positive tubes was chosen, plus the next two dilutions. Where only one dilution produced positive tubes, this dilution as well as the nearest lower and higher dilutions was used.

3.5.5 Sensory analysis

To determine the effect of the different preservation treatments on the sensory acceptability of *Tshidzimba*, a consumer acceptance test was performed on unpreserved, canned, dried and fermented *Tshidzimba* samples.

A hedonic rating scale was used to determine the consumer acceptability of *Tshidzimba*. An evaluation form with a 9 point rating scale ranging from "dislike extremely" to "like extremely" was used by participants to assess the acceptability of the sensory quality characteristics (appearance, taste and texture), and the overall acceptability of *Tshidzimba*.

The consumer test panel comprised 50 students from the University of Pretoria. Recruitment was carefully done, only individuals that were familiar with and regularly consumed *Tshidzimba* were chosen.

The sensory evaluation test was performed in the lecture hall at the Department of Food Science, University of Pretoria. At least 25 participants were accommodated at a time, and they were divided into two groups of which each group had a session to attend. The participants were supervised during the test session. Individual assessment was followed throughout the test i.e. communication between panellists was not allowed. Daylight conditions were used throughout the testing period.

Cold samples (room temperature) (approximately 30 g of *Tshidzimba*) were portioned into porcelain containers and covered with aluminium foil. The dried *Tshidzimba* (200 g) was reconstituted with 500 ml of tap water and allowed to boil for 3 min at 95°C. Before serving, samples were coded with 3 digit numbers and served in a randomised fashion to minimise bias. Panellists were familiarised with the evaluation forms description. Explanation of the terms used to describe various characteristics of samples was given to panellists where it was necessary. Two appendices with regard to sensory evaluation have been included.

3.5.6 Statistical analyses

Statistica for Windows 95 (Statsoft, Inc., Tulsa, USA) was used for statistical analysis. Analysis of Variance (ANOVA) and the least significant difference test (LSD-test) was used to determine whether a difference existed between means of treatments. Means were calculated from replicate data. All comparisons were done at a level of 5% significance.

Appendix 1

An evaluation form for the consumer acceptability test

CONSUMER EVALUATION OF TSHIDZIMBA

Name: ______________________________________

Age : ______________________________________

Sex : ______________________________________

Date : ______________________________________

You are provided with four samples of *Tshidzimba*, which you are required to evaluate their sensory characteristics in terms of their appearance, texture, taste, and overall acceptability. Please, rinse your mouth with water before starting tasting and in between before tasting each sample.

For each sample of meal, please write down how much you like the appearance, texture (how you feel in your mouth), taste, and the overall acceptability of the sample by marking the appropriate block on each scale with a [X].

Sensory evaluation form

Code:

	Appearance	**Texture**	**Taste**	**Overall acceptability**
Like extremely				
Like very much				
Like moderate				
Like slightly				
Neither like nor dislike				
Dislike slightly				
Dislike moderately				
Dislike very much				
Dislike extremely				

Comments:____

____

Thank you for taking your time to participate in this consumer sensory evaluation of Tshidzimba.

Appendix 2

Master sheet: 9 point hedonic scale for the sensory acceptability test

MASTER SHEET: 9 POINT HEDONIC SCALE

A = 1
B = 2
C = 3
D = 4

Panellist	Perm.	Serving	Treat.	Code	Appearance	Texture	Taste	Overall accept.
1	4	1	D	915				
	1	2	A	186				
	3	3	C	039				
	2	4	B	976				
2	1	1	A	522				
	4	2	D	660				
	2	3	B	187				
	3	4	C	608				
3	3	1	C	668				
	4	2	D	514				
	2	3	A	104				
	1	4	B	230				
4	4	1	D	589				
	3	2	C	163				
	2	3	B	008				
	1	4	A	085				
5	2	1	B	716				
	3	2	C	067				
	4	3	D	628				
	1	4	A	142				

Note A= unpreserved; B= Dried; C= Canned; D= Fermented

Hedonic point scale; 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; 9= Like extremely

4. RESULTS

4.1. Effects of preservation on the microbiology of *Tshidzimba*

4.1.1 Effect of storage on unpreserved *Tshidzimba* at 25°C on Total Plate Counts, Coliforms, Yeasts and Moulds

Table 8: Effects of storage at 25°C on TPC, Coliforms, Yeasts and Moulds of unpreserved *Tshidzimba*

Time (days)	Yeasts (cfu/g)	Moulds (cfu/g)	TPC (cfu/g)	Coliforms (cfu/g)
0	$<1.0 \times 10^1$a	$<1.0 \times 10^1$a	$<1.0 \times 10^1$a	$<1.0 \times 10^1$a
1	nd[2]	nd	2.95×10^5b	$<1.0 \times 10^1$a
2	7.00×10^4b	4.57×10^4 b	3.89×10^6c	$<1.0 \times 10^1$a
3	nd	nd	5.50×10^6d	$<1.0 \times 10^1$a
4	8.04×10^5c	6.31×10^5c	nd	nd

1 Mean values in the same column with different letters differ significantly from each other ($p< 0.05$)
2 nd= not determined

Significant numbers of Yeasts and Moulds were observed after 2 days of storage.There was a significant increase ($p< 0.05$) in Yeasts and Moulds from day 0 to day 4. The product was mouldy, slimy and had an off-odour on the third day of storage at 25°C. No significant numbers of TPC were observed on day 0. However, there was a significant

increase ($p < 0.05$) in TPC from day 0 to day 1. The numbers of coliforms were very low and did not increase after 3 days of storage at 25°C.

4.1.2 Effect of storage at 25°C on the Total Plate Counts, Yeasts and Moulds of fermented *Tshidzimba*

Table 9: Effects of storage at 25°C on the TPC, Yeasts and Moulds of fermented *Tshidzimba*

Time (days)	Yeasts (cfu/g)	Moulds (cfu/g)	TPC (cfu/g)
0	$<1.0 \times 10^1$a	$<1.0 \times 10^1$a	$<1.0 \times 10^1$a
7	3.63×10^2b	3.02×10^2 b	1.59×10^2 b
14	1.10×10^3c	9.55×10^2 c	3.16×10^2 c
21	1.29×10^3c	1.10×10^3 d	1.26×10^3 d

Mean values in the same column with different letters differ significantly from each other ($p < 0.05$)

Low numbers of TPC, Yeasts and Moulds were observed on day 0. However, there was a significant increase ($p < 0.05$) in Yeasts from day 0 to day 14, Moulds from day 0 to day 21 and the Total plate counts from day 0 to day 21

4.1.3 Effect of storage at 25°C on the Total Plate Counts, Yeasts and Moulds of dried *Tshidzimba*

Table 10: Effects of storage at 25°C on the TPC, Yeasts and Moulds of dried *Tshidzimba*

Time (days)	Yeasts (cfu/g)	Moulds (cfu/g)	TPC (cfu/g)
0	$<1.0 \times 10^1$	$<1.0 \times 10^1$	$<1.0 \times 10^1$
7	$<1.0 \times 10^1$	$<1.0 \times 10^1$	$<1.0 \times 10^1$
14	$<1.0 \times 10^1$	$<1.0 \times 10^1$	$<1.0 \times 10^1$
21	$<1.0 \times 10^1$	$<1.0 \times 10^1$	$<1.0 \times 10^1$

The numbers of TPC, Yeasts and Moulds were low and did not increase during 21 days of storage at 25°C.

4.1.4 Effect of storage at 25°C on anaerobic spore formers in canned *Tshidzimba*

After 21 days of storage at 25°C no anaerobic spore formers were detected in canned *Tshidzimba*.

4.2 Effects of processing on proximate compositions

4.2.1 Effects of cooking and preservation on proximate compositions of *Tshidzimba*

Table 11: Effects of preservation on the proximate compositions (g/100g) of *Tshidzimba*

Treatment	Crude protein		Crude fat		Ash		Moisture
	Dry	As is	Dry	As is	Dry	As is	
Unpreserved	14.82b[1]	5.04	15.99c	5.44	1.78b	0.61	66.01c
Fermented	14.85b	4.18	14.66b	4.13	2.24b	0.58	71.82d
Canned	14.13a	5.11	14.70b	5.31	1.18a	0.43	63.87b
Dried	14.66b	13.81	13.24a	12.47	1.71b	1.62	5.83a

1 Mean values in the same column with different letters differ significantly from each other ($p < 0.05$)

On a dry basis there was not much difference in crude protein between the preserved (canned, fermented and dried) and unpreserved *Tshidzimba*. Differences existed for crude fat between the preserved (canned, fermented and dried) and unpreserved *Tshidzimba*. The unpreserved *Tshidzimba* showed the highest fat content of 15.99 g/100 g, while the dried showed the lowest fat content of 13.24 g/100 g. For ash there was not much difference on a dry basis between the preserved (canned, fermented and dried) and the unpreserved *Tshidzimba*. As would be expected the dried *Tshidzimba* showed the lowest moisture content of 5.83 g/100 g, while the unpreserved, fermented and canned *Tshidzimba* showed similar moisture content.

4.2.2 Effects of cooking and preservation on water activity (a_w) and pH of *Tshidzimba*

Table 12: Effects of cooking and preservation on water activity (a_w) and pH of *Tshidzimba*

Treatment	Water activity (a_w)	pH
Unpreserved	0.91^{c}	6.5^{b}
Fermented	0.86^{b}	3.9^{a}
Canned	0.86^{b}	6.5^{b}
Dried	0.52^{a}	6.5^{b}

Mean values in the same column with different letters differ significantly from each other ($p < 0.05$)

Significant differences existed for water activity between the preserved (canned, fermented and dried) and unpreserved *Tshidzimba*. The unpreserved *Tshidzimba* showed the highest a_w of 0.91, while the dried *Tshidzimba* showed the lowest a_w of 0.52. Fermentation significantly reduced the pH, while other preserved samples (i.e. canned and dried) had the same pH as the unpreserved *Tshidzimba*.

4.2.3 Effects of cooking and preservation on amino acids of *Tshidzimba*

Table 13: Effects of preservation on essential amino acids (g/100 g protein) of *Tshidzimba*

Amino acids	Peanuts (g/100 g)	Maize (g/100 g)	Unpreserved (g/100 g)	Canned (g/100 g)	Dried (g/100 g)	Fermented (g/100 g)	Ideal pattern (infants)*
Histidine	1.70 (65)***	2.42 (93)	1.87 (72)	1.77 (68)	1.97 (76)	1.84 (71)	2.6
Isoleucine	1.85 (40)	2.25 (49)	1.98 (43)	1.94 (42)	2.02 (44)	1.93 (42)	4.6
Leucine	5.14 (55)	12.88 (139)	7.58 (82)	7.71 (83)	8.04 (87)	7.63 (82)	9.3
Lysine	3.26 (49)	1.77 (27)	2.28 (35)	1.97 (30)	2.61 (40)	2.04 (31)	6.6
Methionine	1.07 (26)	1.61 (38)	1.47 (35)	1.28 (31)	1.30 (31)	1.78 (42)	4.2**
Phenylalanine + Tyrosine	7.77 (108)	8.70 (121)	7.91 (110)	7.88 (109)	8.66 (120)	7.89 (110)	7.2
Threonine	2.78 (65)	4.03 (94)	3.01 (70)	2.98 (69)	3.08 (72)	2.88 (67)	4.3
Valine	2.66 (48)	3.54 (64)	2.81 (52)	2.85 (52)	3.02 (55)	2.83 (52)	5.5

* Data from WHO (1985)

** Cystine plus Methionine

*** Percentage of ideal pattern

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The essential amino acid values of the different *Tshidzimba* treatments were intermediate between the maize and peanut values. Differences existed for essential amino acids between the preserved (canned, fermented and dried) and unpreserved *Tshidzimba*. The dried *Tshidzimba* showed the highest lysine of 2.61 g/100g protein, while the canned showed the lowest (1.97 g/100 g protein). Fermented *Tshidzimba* showed the highest methionine (1.78 g/100 g protein), while canned showed the lowest (1.28 g/100 g protein).

4.3 Sensory evaluation

Table 14: Effects of different preservation treatments on the sensory characteristics[1] of *Tshidzimba*

Treatment	Appearance	Texture	Taste	Overall acceptability
Unpreserved	7.28b[2]	7.48c	7.98d	7.68d
Dried (reconstituted)	6.80b	6.66b	6.78c	6.80c
Canned	5.62a	6.16b	5.62b	5.78b
Fermented	5.48a	5.26a	3.88a	4.08a

1 Sensory characteristics were graded on the scale 1= Dislike extremely; 9= Like extremely

2 Mean values in the same column with different letters differ significantly from each other ($p < 0.05$)

In general, there were significant differences ($p < 0.05$) between unpreserved, fermented, canned and dried *Tshidzimba* in appearance, texture, taste and overall acceptability. In all attributes the mean score values decreased from unpreserved to dried, to canned to fermented.

5. DISCUSSION

It was noted that unpreserved *Tshidzimba* had a shelf life of two days when stored at 25°C. This was reflected by the high total plate counts (10^6 cfu/g) on the third day of storage which is above the cut-off point of 10^5 cfu/g. According to Jay (1998) foods are free of any sign of microbial spoilage when microbial counts are less than 10^3 cfu/g. The same is true for most foods that contain between 10^4 to 10^5 cfu/g viable bacteria. With counts between 10^5 to 10^6 cfu/g some products are in state of spoilage incipiency. However, *Tshidzimba* only visually showed a change in appearance (mouldy and sliminess) and produced an unacceptable off-odour on the third day. On day zero and day one, there was little growth as expected because the number of bacteria in the product was still low after the cooking process. Heating reduces the number of organisms and destroys some life threatening microbial toxins (Jelen, 1985). It also inactivates enzymes that contribute to spoilage. Those organisms that survived the cooking process proliferated to unacceptably high levels after only two days of storage at 25°C. The rapid spoilage was probably caused by the high water activity (0.91) of the unpreserved product and also the high pH (6.5) of the product. Water activity is widely used as a determinant of physiological activity (Barnwart, 1989). Bacteria grow well at water activity above 0.9 and with the water activity of 0.91 and pH of 6.5 unpreserved *Tshidzimba* is a good medium for microbial growth.

Very low coliform counts were found in unpreserved *Tshidzimba* throughout the period of storage. This was not surprising as coliforms are normally indicators of poor hygiene and possibly contamination (Jay, 1998). Good sanitation of equipment and utensils was applied with no hands or any body contact with product allowed during cooking and transferring of the product to the containers to be stored.

Yeasts and moulds did not seem to present any problems during the first day of storage of the unpreserved *Tshidzimba* but their counts increased significantly on the second and fourth day. Their slow growth rate during the first day of storage could be due to thermal injury during cooking process. Hutton, Koskinen and Hanlin (1991) reported that post-

heating events like storage conditions (e.g. changes in humidity, temperature, pH, light intensity and Eh) influence microbial recovery and lead to an increase in microbes. This could have been the cause of the sudden rise in yeasts and moulds number.

Canning, drying and fermentation were used as preservation treatments for the extension of the shelf life of *Tshidzimba*. The preservative factors involved in extending the shelf life of *Tshidzimba* using the above preservation treatments were heat, pH, packaging material and water activity. For preservation by canning, the preservative factors involved were heat and packaging material, while heat and water activity were involved in preservation by drying treatment and for preservation by fermentation treatment the factors involved were heat, low pH and packaging material. In contrast, heat was the only preservative factor in the unpreserved *Tshidzimba* and this made it have a short shelf life compared to the preserved samples with more than one preservative factor.

The water activity of the fermented *Tshidzimba* was 0.86 which favours the growth of spoilage fungi, yeasts and some bacteria (Barnwart, 1989, Jay, 1998). The pH of fermented *Tshidzimba* of 3.9 was below the growth range of many bacteria (Jay, 1998). The pH was lowered with lactic acid during fermentation. With the combination of low pH, heat and packaging material it was not surprising to find low counts of total plate counts, yeasts and moulds in fermented *Tshidzimba* after storage at 25°C for 21 days.

After 21 days of storage the total plate counts of fermented *Tshidzimba* were at 10^3 which is far below the spoilage cut-off point of 10^5 (Jay, 1998). This could have been caused by the selective medium which fermented *Tshidzimba* provided because of its low acidic pH of 3.9. Yeasts and moulds also did not seem to present any problems during storage of fermented *Tshidzimba*. Lopez (1987b) reported that acid increases thermal lethality of microorganisms.

Drying reduced the water activity significantly from 0.91 (unpreserved) to 0.52. The explanation for the decrease of water activity in the dried sample was due to reduction of moisture during the drying process of *Tshidzimba*. The a_w of 0.52 is far below the cut-off

point of microbial activity of 0.6 as reported by Jay (1998). The pH of dried *Tshidzimba* of 6.5 was within the growth range of large number of bacteria, but due to the low a_w it was not surprising to find counts of less than 10 cfu/g for both total plate counts and yeasts and moulds count after 21 days of storage in sealed plastic bags at 25°C. The lowered a_w together with the heat treatment and packaging material contributed to low microbial counts in the dried *Tshidzimba* and hence extended shelf life.

The a_w of canned *Tshidzimba* was 0.86 which favours the growth of spoilage bacteria (Barnwart, 1989). The pH of canned *Tshidzimba* of 6.5 was within the growth range of toxic producing anaerobic bacteria (Jay, 1998). After 21 days of incubation at 37°C, canned *Tshidzimba* was found to contain no anaerobic spore producing bacteria. This is probably because they were destroyed during the retorting process which was done at 116°C in 70 min at $F_o = 6$ min. Lopez (1987b) reported that in order to assure safety, low-acid (pH >4.6) foods must be fully retorted (115°-121°C) at $F_o = 3$ min. The cans used as packaging prevent recontamination after retorting.

In most cultures, eating habits are based on the available agricultural raw materials (Nkama *et al*., 1995). Traditional cereals and legume crops play important roles in the diet of many people in developing countries, and are major sources of proteins, carbohydrates, vitamins and minerals. The two grains do not provide a balanced diet individually because they lack some essential nutrients. Cereal crops like maize can provide essential sulphur containing amino acids but lack lysine (Bressani, 1993, Cook, 1993). Legumes are rich in lysine and essential fatty acids but lack sulphur containing amino acids (Nwokolo, 1996). Therefore, for the grains to provide essential nutrients complementation is important like in *Tshidzimba* (maize-peanut composite) porridge.
The protein content of peanuts used in this trial was within the range of values reported by other authors such as Rhee (1985), but the maize grits protein content was below the range of values reported by Kent & Evers (1994). The reason could be that authors' value was based on whole maize grains, while the grits lack the germ and pericarp. The germ and pericarp are removed during milling leaving the grits composed mainly by endosperm. Their removal affects the protein content because they are rich in protein and

lipids. The addition of peanut is expected to overcome the protein and essential fatty acids deficiency of maize. Peanut as a legume is limiting in the sulphur-containing amino acids, cysteine and methionine, but contain sufficient lysine (Wijeratne, 1992) to overcome the lysine deficiency of maize as cereal. Lysine deficiency is a major cause of malnutrition in developing countries (Serna-Saldivar & Rooney, 1995).

The protein content of the processed *Tshidzimba* was higher than that of raw maize grits. The increases in total protein and fat on dry basis, from raw maize grits to processed *Tshidzimba* samples were due to complementation by peanuts. The protein content of unpreserved *Tshidzimba* obtained (14.8/100 g dry basis was not much different with that reported by Oyeleke (1992) (14.1g/100 g dry basis) for the similar related traditional Nigerian dish *Egbo*.

There was not much difference in protein content on a dry basis between the preserved (canned, fermented and dried) and unpreserved *Tshidzimba*. This was to be expected because preservation does not affect the crude protein content but the bioavailability and quality of protein. The fermented *Tshidzimba* protein content on a dry basis was slightly higher than that of unpreserved *Tshidzimba*. This could have been due to the distribution of nutrients within the product caused by reduction in dry matter from the metabolism of carbohydrates. Chavan and Kadan (1989) attributed the small increase in protein observed with natural fermentation to the loss of dry matter.

The observation that on dry basis, drying decreased the fat content compared to the unpreserved *Tshidzimba* was expected. Hall and Pither (1991) reported that unsaturated lipids are prone to oxidation when heated in the presence of air or oxygen. In case of *Tshidzimba* drying was done using a forced-draught oven and that could have promoted oxidation of lipids. The decreases in fat content (14.7 g/100 g) of fermented *Tshidzimba* compared to 16.0 g/100 g of unpreserved *Tshidzimba* were not expected. Griffith, *et al.*, (1998) reported no decrease in fat content through fermentation when cereal-legume composites related to *Tshidzimba* were fermented In this investigation decrease in fat content on fermentation could have been due to the boiling of fermented *Tshidzimba* after

fermentation that could have resulted in lipid oxidation. In addition breakdown of lipids by microorganism during fermentation process could lead to decrease in fat content of fermented products.

Drying and fermentation had no effect on ash content compared to unpreserved *Tshidzimba,* but canning appeared to have slightly decreased the ash content. Nevertheless, the observed losses may not be appreciable enough to be a cause for concern because ash content represents the total mineral content in foods.

Tshidzimba showed an increase in lysine and sulphur-containing amino acids contents compared to maize and peanut individually. The reason for this was the complementation of lysine and sulphur-containing proteins by peanut and maize respectively. The lysine content of unpreserved *Tshidzimba* (2.28 g/100 g protein) was lower than that reported by Oyeleke (1992) (3.56 g/100 g protein) the similar traditional Nigerian dish *Egbo*. This difference may be attributed to a difference in type of the maize product used. In *Tshidzimba*, maize grits were used, while in traditional Nigerian dish whole maize grains were used. With peanut, differences in cultivar and growing conditions could also have contributed to high lysine content. Low Maillard reaction due to low temperature used during drying could have led to the higher level of lysine in dried *Tshidzimba* compared to canned *Tshidzimba*.

The methionine content of fermented *Tshidzimba* (1.78 g/100 g) was the highest of the four samples. This was not surprising because during fermentation, fermentative microorganisms are known to produce some amino acids while fermenting food products (Hickey, 1954). The low levels of methionine in canned *Tshidzimba* compared to unpreserved *Tshidzimba* could be attributed to high temperatures used during canning (116°C/70 min). Camacho, Banados and Fernandez (1989) in the canning of maize-sweet lupin composite *Humitas* reported that some amino acids are thermosensitive and are affected by sterilisation.

The lysine and methionine values of *Tshidzimba* are lower than the estimated amino acid requirements for infants, but higher than the estimates of amino acids requirements for adults of lysine (1.6 g/100 g protein) and methionine (1.7 g/100 g protein) (WHO, 1985) (Young and Pellet, 1994) and so *Tshidzimba* is a relatively good source of lysine and sulphur-containing amino acids for adults.

A consumer acceptability test was performed in order to find out which of the preserved *Tshidzimba* samples is closest to the traditionally prepared *Tshidzimba* in preference. Although the consumer overall acceptability tests results showed that the dried *Tshidzimba* was not as acceptable as the unpreserved *Tshidzimba*, the sample was more acceptable compared to canned and fermented samples. The sensory scores for canned and fermented *Tshidzimba* indicated however, that they were less acceptable than the traditional *Tshidzimba* and dried *Tshidzimba* in all attributes but texture. The decrease in the overall acceptability of the preserved *Tshidzimba* perceived by the panellists is attributable to the loss in product appearance, texture and taste with different preservation methods (i.e. canning, drying and fermentation). The retention of appearance observed by the participants in the dried sample could be due to low Maillard reaction attributed to low temperature (50^0C/ overnight) used during drying. According to Fellows (1990) low temperatures reduce rate of Maillard reaction. The loss in appearance observed by the panellists in the canned sample compared to the unpreserved *Tshizimba* could be due to Maillard reaction and caramelisation, which might have occurred during canning. Fellows (1990) states that time/temperature combination used in canning change the colour of most naturally occurring pigments. In addition to the destruction of pigments by heating, coloured products may be formed due to caramelisation of sugars and Maillard reaction.

The panellists observed no textural difference between canned and dried *Tshidzimba*, but a difference was observed compared with the unpreserved *Tshidzimba*. This was expected because higher temperatures and longer processing period were used in canned and dried *Tshidzimba* compared with the unpreserved *Tshidzimba*. According to Urbain (1986) heat processing damages or destroys membranes and disrupts intercellular structures, resulting in cell separations.

The change in texture that was observed in the fermented *Tshidzimba* was expected. The textural loss could be due to amylase and protease activities. Cook (1993) reported that

complex changes to proteins and carbohydrates during fermentation soften the texture of fermented products. This is due to hydrolysis of protein to amino acids and peptides by proteases and hydrolysis of starch to sugars and dextrins by amylases. The activities of these two enzymes presumably caused a softer product compared to the unfermented *Tshidzimba*, since some of the panellists reported that the fermented sample was soft and seemed overcooked.

Regarding the taste of the three preserved *Tshidzimba* (canned, dried and fermented) products, drying had less effect on the taste compared to the unpreserved sample, but canning and fermentation had a recognisable effect. The possible explanation for drying to have a slight effect on taste could be due to loss of some volatile components from food during drying. According to Fellows (1990) heat not only vapourises water during drying but also causes loss of volatile components from the food. In the case of canned *Tshidzimba* this could be due to Maillard reaction and caramelisation. Maillard reactions contribute flavours to heated foods such as cereal products and these flavours can be desirable or undesirable (Pither, 1993). Some of the panellists reported that the fermented *Tshidzimba* had a sour taste. This was expected because the decrease in pH due to fermentation lead to production of organic acids. The acids could have given the product an acidic or sour taste and this is not typical of the traditional *Tshidzimba*.

6. CONCLUSIONS AND RECOMMENDATIONS

Canning, drying and fermentation were successfully used to preserve *Tshidzimba*. The preserved *Tshidzimba* had longer shelf-life compared to unpreserved *Tshidzimba*. Lowering of pH was the reason for long shelf-life of fermented product, while sterilisation was reason for long shelf-life of canned product and low a_w was reason for long shelf-life of dried product.

Though the preserved *Tshidzimba* had high content of essential amino acids it did not meet the requirements for weaning foods as indicated by the WHO (1985). This short fall could be met by fortification with a higher proportion of legume grains to improve the lysine content. However, *Tshidzimba* met the estimated amino acid requirements for adults (Young & Pellet, 1994).

According to sensory evaluation by untrained panellists, fermented *Tshidzimba* had the low acceptability, probably because the panellists who were familiar with the unpreserved *Tshidzimba* have never tasted it in the fermented form. Dried *Tshidzimba* was perceived to have a firmer texture, probably due to longer heating periods the dried *Tshidzimba* was exposed to compared to unpreserved *Tshidzimba*. This is one area where further research could help to determine the most appropriate time/temperature combination that can affect texture the least without compromising the safety of the preserved products.

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