SHELFLIFE OF DRIED VEGETABLES

BY

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A THESIS

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DEDICATION

This thesis is dedicated to my family in appreciation of their encouragement, confidence and support towards my academic work at the University of Zambia.

Thank you for the support and the encouragement.

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All that we know is a sum of what we have learnt from all who have taught us directly and indirectly. I am forever indebted to the countless outstanding men and women who, through their commitment and dedication to becoming the best they could be, have inspired me to do the same.

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LIST OF ABBREVIATIONS

AOAC	-	Association of Analytical Chemists
BAM	-	Bacteriological Analytical Manual
CFU	-	Colony Forming Unit
DTA	-	Dextrose Tryptose Agar
EU	-	European Union
FAO	-	Food and Agriculture Organisation
MAFF	-	Ministry of Food and Fisheries
MPN	-	Most Probable Number
PAM	-	Program Against Malnutrition
PPM	-	Parts per million
WHO	-	World Health Organisation

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ABSTRACT

This study investigated the shelf life of dried vegetables, processed by the Greenhill Ulimi Women's Group. The objectives of analyzing the vegetables were

- To determine the microbial quality of dried vegetables.
- To determine the nutrient content of dried vegetables.
- To determine the shelf life of dried vegetables.

The dried vegetables covered include dried pumpkin leaves, dried cowpea leaves, dried luncomba leaves (delele), dried cabbage and dried rape.
The research study covered two areas of analysis, that is chemical and microbial analysis. Chemical analysis gave information on nutrient content,quality and safety parameters like toxins and peroxides. The dried vegetables stored at 25°C were analysed for moisture, protein, fat, acid-insoluble ash, vitamin A, fibre and aflatoxins and the results are as shown in the tables and bar chart graphs. Microbial criteria are also used to establish product safety,quality and shelf life. Shelf life study, microbiologically was done at two temperatures. Some dried vegetables were stored at 25°C and 45°C. The 25°C temperature simulated ordinary room temperature. The 45°C simulated abusive temperature. Results obtained showed how these vegetables stored at these temperatures vary in terms of microbial quality and hence shelf life. The duration of study was 8 weeks.
Some vegetables had results reported for storage at 25°C only.

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1.0 INTRODUCTION

Shelf life is the period within which food can be stored and be desirable and suitable for consumption. If one or more attributes of a food reaches an undesirable state, the food is considered undesirable and unsuitable for consumption and it is said to have reached the end of its shelf life.

Plant products especially vegetables and fruits have been processed on a small scale for a long time in rural Zambia. In the rural areas, vegetables are sundried on mats and trays, the traditional way. The use of solar dryers in small scale processing of vegetables is gaining ground. These rural processed vegetables are available on the commercial market in small quantities, for various reasons like hygiene and the fact that they are undocumented .

Traditionally, drying is used to preserve and extend the shelf life of plant products. This is due to the fact that most are seasonal, hence the need to preserve them.

There are about a dozen kinds of cultivated leafy vegetables in Zambia and twenty to thirty, which are collected from the bush (Whitby 1972). This research dealt with two types of dried vegetables, which are, traditional and horticultural vegetables. Some traditional vegetables normally dried include the following: baobab leaves, pumpkin leaves [Cucurbita pepo], bean leaves [Phaseolus vulgaris], jute leaves [Delele], sweet potato leaves [Impomea batatas] and cow pea leaves. Some horticultural vegetables include: cabbage [Brassica oleracea],

okra [Hibiscus esculuntus], rape [Brassica rapa], spinach [Amaranthus spp], tomatoes [Lycopesicum esculentum] and pepper (Muntemba 1977).

Traditional vegetables are mostly consumed in rural areas of Zambia, while the horticultural ones are mostly consumed in the urban areas but are also consumed in both urban and rural areas. These vegetables are either cooked in oil or cooked with groundnut powder or mixed with dried fish or meat. The vegetables are eaten as relish with nshima or accompanied with meat and nshima, in most parts of Zambia.

During the drying process, vegetables lose most of the moisture, which results in an increased concentration of nutrients in the remaining mass. Nutrients of importance found in most leafy vegetables are carotene [vitamin A], iron, calcium, protein, carbohydrates, fat and vitamin C which is heat sensitive and is lost during cooking and during sun drying due to the intensive heat.

2.0 STATEMENT OF PROBLEM

Despite some studies having been done on food products produced under rural processing, little is known about their microbial quality and hence consumers are doubtful as to whether they are suitable for consumption, the quality is not well documented as well as the nutrient content of these foods. This study will evaluate and discuss the quality/shelf life and nutritional value of these plant products (dried vegetables). Recommendations will be made on how to improve the quality, food safety and shelf life of the dried vegetables.

3.0 OBJECTIVES

The objectives of the study are as follows:

1. to determine microbial quality of dried vegetables;
2. to determine the shelf life of dried vegetables;
3. to determine the nutrient content of dried vegetables.

4.0 RATIONAL

Shelf life determination of dried vegetables is crucial as it helps improve the quality of rural processed Zambian plant products (dried vegetables).

Dried vegetables can significantly contribute to food security. Household food security is defined as access by all households at all times to sufficient food for an active and healthy life of all its members. Dried vegetables have the potential

of contributing to household food security, thereby reducing the problems of malnutrition and hunger. This is because sundrying, a method used in vegetable preservation, is relatively simple and cheap and can therefore be used on a commercial level, thus adding to the nation's economic wealth. Additionally dried vegetables can be used as relief foods, to those affected by food shortage. Micronutrient malnutrition owing to unavailability of certain seasonal foods (vegetables and fruits) in most rural areas, would be minimized by the availability of the dried vegetables which would prevent certain vitamin deficiencies.

The process of vegetable preservation has the potential of creating employment, especially for the women and youth, hence aiding in poverty reduction on the national level and individual level in that it can encourage self-reliance. An article on food security prepared for The Ministry of Agriculture, Food and Fisheries revealed that lack of information or poor planning may lead to food losses. In other instances, food losses may be the result of climatic conditions, physical facilities, level of technology, cultural practices, prices of farm inputs, negative market prices and lack of personal motivation. Some factors that lead to the cumulative causes of post–harvest food losses in developing countries, thus causing food insecurity include inefficient harvesting and handling methods, poor processing techniques, inadequate methods of storage and distribution and even poor preparation of foods in the home. The actual causes of food losses can be grouped into two main categories, the primary and the secondary. The primary causes are those that directly affect the food. These are the biological, microbiological, chemical, biochemical reactions and physiological. The

secondary causes are those that encourage the conditions which result in the primary cause of loss.They are usually the result of inadequate training, inadequate or non-existent storage structures, unsuitable technologies and ineffective quality control (Component 14: Food Security, MAFF 1998).

5.0 LITERATURE REVIEW

The shelf life of a food is the duration within which it can be stored and yet be desirable and safe for consumption. The actual length of the shelf life of any given food product will depend on a number of factors such as processing method, packaging and storage conditions. Environmental factors such as temperature, humidity, oxygen and light (extrinsic factors) can trigger several reaction mechanisms, which may lead to food degradation as revealed by (Adams and Moss, 2000). As a consequence of these mechanisms, foods may be altered to such an extent that the consumer either rejects them or they may become harmful to the person consuming them.

Chemical, physical and microbiological changes are the leading causes of food deterioration.

Microbial growth in foods results in food spoilage with the development of undesirable sensory characteristics and in certain cases the food may become unsafe for consumption. It has been revealed that fresh produce are capable of

supporting the growth of any type of microorganism due to their high water activity and nutrient content. (Adams and Moss, 2000).

Foods of plant origin are diverse in composition. Consequently, patterns of microbiological spoilage differ substantially, as seen especially in vegetables. The pathogencity of certain micro-organisms is a major safety concern in processing and handling of foods. Upon ingestion, micro-organisms such as *salmonella* species and *E. Coli* strains cause infection while others such as *Aspergillus flavus,* and *Staphylococcus aureus* produce chemicals in foods that are toxic to humans. An example is Aflatoxins which are produced by *Aspergillus flavus* and *Aspergillus parasiticus.* These moulds are acutely toxic as well as carcinogenic. They are found in many agricultural products especially groundnuts and maize (Adams and Moss, 2000). WHO standards for aflatorin is 30µkg, while the FAO standard is 50µg and the EU standard is <5 PPM. Some countries have set lower values, for their standards than WHO and FAO.

Studies by the department of Food Science and Technology (2000) for PAM on quality and safety of some food products processed in the rural areas in Zambia revealed that *E. Coli* analysed in green dried cabbage at storage temperature of 25(C, were detected in weeks 3, 5 and 7 with counts of >1100, 460 and >1100 respectively.

Adams and Moss (2000) revealed that *E.coli* is a natural component of the human gut flora and its presence in the environment or foods generally indicates fecal contamination. *E.coli* is an indicator organism which when present in a

sample can mean that other pathogens may be present. Studies by the department of Food Science and Technology (2000) revealed that the green dried cabbage and cassava products had *fecal coliforms* with an MPN at less than 3 which is satisfactory, indicating good microbiological quality.

Adams and Moss (2000) revealed that *thermopiles* are microorganisms, which grow at elevated temperature. The microorganisms' growth exhibits a minimum optimum and maximum temperature at which growth can occur. Minimum temperatures are between 40 - 45° c, optimum 55 -75° c and maximum 60 - 90° c. At temperature above maximum for growth microorganisms are killed.

Food legislation in many developed countries requires most foods to carry a date of maximum durability or otherwise known as expiry date. The expiry date is used when the food is microbiologically highly perishable and therefore likely after a short period to contribute an immediate danger to human health. Zambia is yet to set a standard for dried vegetables.

Zambia, like several African countries, is faced with the problem of seasonal hunger. Inadequate storage and preservation facilities in several parts of Zambia have resulted in food wastage, particularly during periods of bumper harvest of perishable foods such as vegetables and fruits. The National Food and Nutrition Commission revealed that of all the methods of preserving vegetables, sun drying is the simplest and the least expensive because it uses natural energy. In Zambia, vegetables are put in open baskets and left under direct sunlight. In

certain cases, vegetables are spread on mats and then dried. On the whole sun drying practices of most vegetables have changed very little over the years. Muntemba 1977 in Small scale Vegetable and Fruit Preservation in Zambia revealed that the process of drying differs from one family to another in the same area. Some people dry their vegetables without blanching. Some do blanch and add some salt, while others just blanch and then sundry them. However, the National Council for Scientific Research in their study revealed that it is important to blanch the vegetable before drying in order to inactivate some enzymes, which may otherwise destroy the nutrients of the leaves during drying and storage.

Preservation of vegetables through drying can be used as a means of curbing the existing problems of malnutrition, hunger and food shortage. The dried vegetables can be used as a means of relief to those that are vulnerable to food insecurity and thus improving the food security situation in Zambia. The Food Legumes For Better Nutrition And Health [Fereidoon et al 1997] revealed that, the current status of household food security in Zambia, by 1997 was, 33% (3.6 million people) of the total of about (9.2 million) of the Zambian population was vulnerable to food insecurity.

6.0 METHODOLOGY

The research adopted the quantitative design. This design was divided into two areas, that is chemical and microbiological analysis. Chemical analysis gave information on nutrient content, quality and safety parameters like toxins and peroxides. The microbial criteria are also used to establish product safety, quality and shelf life. Dried vegetables were analysed using two storage temperatures. Some were stored at 25° C while some were stored at 45° C in the Food Science laboratory, in order to observe shelf life. The 25° c temperature simulates ordinary or room temperature while storage at 45° c simulates abusive temperature or extreme temperature found in some parts of the country.
The duration of the research study was 8 weeks.

6.1 Microbiological analysis

This was carried out in the food microbiology laboratory, were some dried vegetables were analysed for specific micro-organisms. The micro-organisms which were analysed include coliforms *Enterobactriaceae, yeasts* and *moulds, fecal coliforms, E.coli* and *thermopiles.*

For the analysis of *coliforms*, *Enterobactriaceae, yeasts, moulds* and *thermophiles*, the samples of dried vegetables were made to stand for an hour in Buffered peptone water. It is a pre-enrichment medium and it also provides conditions for resuscitation of cells that have been injured by processes of food preservation. A series of dilutions of 25g of each sample were prepared (1.0 x

10^{-3}, 1.0 x 10^{-4}, 1.0 x 10^{-5}, 1.0 x 10^{-6}), using ringer's solution, so that at least one dilution yielded 100-200 colonies from a 1ml aliquot. These 1ml aliquots were transferred to petri dishes and the required amount of medium was added.

Enterobactriaceae and *coliforms* were enumerated using marconkey agar 3 using the pour plate method. When present these are indicative of the standard of hygiene used in the manufacture of the food product including type of water used.

Yeasts and moulds were enumerated using Rosebengal Chlorophenical by pour plate method. *Yeasts and moulds* are spoilage organisms and are usually associated with taints and off-flavors in stored foods. They are the major factors in determining the shelf lives of food products.

E.coli and *faecal coliforms* were enumerated using the MPN technique followed by an indole test. A series of dilutions for the samples of dried vegetables, for *E.coli* and *faecal coliforms* analysis, was prepared. (1.0 x 10^{-1}, 1.0 x 10^{-2}, 1.0 x 10^{-3}). From the dilutions 1ml aliquots of each dilution was transferred to test tubes containing the broth.

Thermophiles were enumerated using DTA agar using the pour plate method.

6.2 Chemical Analysis

Dried vegetables were analysed for moisture, protein, fat, acid-insoluble ash, vitamin A, fibre and aflatoxins.

Knowledge of chemical composition is essential in determining quality and ensuring that high quality products are produced.

Moisture Determination

The determination of moisture is essential in order to know the dry matter content of the food stuff. It is the dry matter fraction of food which contains the essential nutrients namely carbohydrates, proteins, minerals, and vitamins. Moisture determination also gives information on the efficiency of drying and also on the amount of water ledt in the dried product. If this water is too much the product will not last during storage. The determination of moisture was done using the official method (925.09,1998). The sample was ground and mixed to uniformity prior to analysis.

Protein Determination

Protein is essential in the diet because it is required for promoting growth and for the building and upkeep of the body tissues. Protein determination was done using the Kjeldahl method.

Fat Determination

The determination of fat is essential because, fat in the diet serves as a carrier for fat soluble vitamins and is essential for the absorption of carotene. Fat also supplies the essential fatty acids, which are needed by the body and brain development. Fat determination was done using the method (AOAC, 1998, Pearson's 1981).

Acid insoluble Ash Determination

The Acid-insoluble ash is a measure of the contamination of the sandy matter in dried vegetables. Acceptability of dried vegetables is limited due to high levels of sandy matter which makes eating them unappealing. Sand matter content is a quality indicator in dried spices and this can also be useful in dried vegetables. The contaminants are usually silicates which remain insoluble

in acid except in Hydrogen Bromide. It was determined using the method (Pearson's, 1997). The sandy matter is obtained by boiling the ash or water insoluble ash with 25ml of 10% m/m HCL for 5 minutes, filtering through an ashless filter paper and thoroughly washing with hot water. The filter paper is then ignited in the original dish, cooled and weighed.

Vitamin A Determination

Vitamin A is a fat soluble vitamin and is essential in the diet. It is important for vision, formation and maintenance of skin. It is essential for the intergrity of epithelial tissues and is a stimulus for new cell growth.It is necessary for maintaining the eye in healthy conditionand for proper vision in dimlight. A continued deficiency of this vitamin in the diet causes night blindness, reduced resistance to infection phrynoderma or toad skin, xerophthalmia (dryness of the conjunctiva of the eyes), Bitot's spots (grayish patches on the white of the eye and keratomalacia (opacity of the cornea), Swaminathan et al 1981.

Fibre Determination

Fibre is important in the diet because it provides bulk for peristatic action and facilitates the passage of material through the bowel. The improved bowel movement causes more rapid removal of unabsorbed breakdown products, which otherwise cause stomach irritation and perhaps encourage conditions conducive for the development of cancer. Fibre was determined using the method (AOAC 1995, Pearson's 1997)

Aflatoxin Determination

The determination of Aflatoxins is essential because, it indicates the presence of Aspergillus flavus which infects growing plants and may produce toxic metabolites before harvesting and storage. They are acutely toxic as well as carcinogenic. Aflatoxins were determined using the method (AOAC 1998) To determine aflatoxin, some weighed sample is mixed with celite and water and chloroform for 30 minutes. Thereafter it is filtered.

Using a syringe, 20 ml of the filtrate is injected on to the thin layer Chromatography plate. The plate is then placed into solution 1 until solvent front Is at least ¾ up front. The plate is then placed in solution 2. The thin layer Is then dried. Qualitatively, the distance is read an compared to the standard Spot of known aflatoxin.

6.3 TYPES OF VEGETABLES USED

TRADITIONAL VEGETABLES	HORTICULTURAL VEGETABLES
1. Dried Pumpkin leaves	1. Dried Cabbage
2. Dried Cowpea leaves	2. Dried Rape
3. Dried Lunkomba (Delele)	

7.0 RESULTS AND DISCUSSION

7.1 CHEMICAL ANALYSIS

5 Dried vegetable samples were analysed in duplicates for Moisture, Protein, Fat, Acid-insoluble Ash, Vitamin A, Fibre and Aflatoxin. The samples were stored at a temperature of 25°C.

MOISTURE

Moisture determination in foods is important in that it gives information on the amount of dry matter known as total solid after water removal. Water content is very important to a food processor (Nielsen, 1998). Moisture is a quality factor in the preservation of dried vegetables and it affects their stability. Reduced moisture makes storage of most products that are dried possible. Calculation of nutritional values of foods is made possible through knowing the moisture content data (Nielsen, 1998). The shelf life of foods to a large extent is determined by water. Water is important for microbiological, chemical, biochemical and physiochemical stability of foods. In dried vegetables reduced moisture content affects the way they are packaged and stored.

Water content alone is not a reliable indicator of food stability since it has been observed that food with the same water content differ in their perishability due to differences in the way water associates with other constituents in a food (Fennema, 1996).

The relationship between water activity and water content expressed as the ratio of water/100g dry matter is called a sorption isotherm. It consists of three distinct areas. The high moisture range with water activity at one, the low moisture range which has water activity less than 0.5 in which dry agriculture products such as dry vegetables fall (Fennema,1996). In this group of foods there are large variations in water activity values. This means that small changes in water content will drastically affect the water activity. This explains why some foods spoil easily with small increases in moisture. Sorption isotherm is also used to determine the moisture content, which will prohibit growth of microorganisms of interest.

The moisture content of the dried vegetables which were analysed ranged from 8.98% - 13.65%. Information on dry vegetables chemical composition is limited in Zambia, most information covered in the Zambian food composition table is on fresh vegetables.

Mazala (1971) reports that dried pumpkin leaves have moisture content of 19%. Moisture was determined in the following dried vegetable samples see (Tables 1- 5) which included dried pumpkin leaves, dried cowpea leaves, dried lunkomba, dried cabbage and dried rape.

Moisture content as depicted from the tables(1-5), for dried pumpkin leaves was 11.62%, for dried cowpea leaves was 12.51%, for dried lunkomba was 8.98%, for dried cabbage was 13.65% and for dried rape was 9.38%. According to (Fennema, 1996) the moisture sorption isotherm of dried vegetables with moisture content in the range 6.29-11.85% have intermediate moisture levels with water activity of 0.5 to 0.87. This is the range in which the analysed vegetables fall. In this water activity range other intermediate foods can be stable, but dried cabbages will not be stable and will have limited shelf life. Some microorganisms, can cause spoilage in the vegetables such as yeasts and molds.

PROTEIN

Protein content in the dried vegetables was analysed and the results are as shown in the tables (1-5). Protein content ranged from 0.16 – 0.35% in the dried vegetables which were analysed. These results showed that dried vegetables are a poor source of protein.

Protein in the diet is required for promoting growth and for the building and up keep of the body tissues. Additionally they are necessary for the proper functioning of metabolic and digestive enzymes, blood proteins and hormones. Deficiency of proteins in the diet of adults results in loss of weight, reduced resistance to the infection and odema. Prolonged deficiency of proteins in the diet of the children results in a condition known as Kwashiorkor characterized by

general weakness emaciation reduced resistance to infections, odema and dry lusterless skin with pigmentation (Swamnathan et al, 1986).

FAT

Fat determined in the dried vegetables ranged from 1.73% to 4.46%. Fat content in dried pumpkin leaves was 2.6%, in cowpea leaves was 4.46%, in lunkomba was 1.73%, in cabbage was 2.3% and in rape was 2.54%. There is a question as to whether the fat content in the dry vegetables is just the equivalent of an extraction and not necessarily fat extraction. Results showed that dry vegetables are not good sources of energy.

Fat serves as a concentrated source of energy and it is stored in the layer beneath the skin. Fat in the diet serves as a carrier for fat soluble vitamins and is essential for the absorption of carotene (provitamin A). Fat also supplies the essential fatty acids, which are needed by the body and brain development. Prolonged deficiency of fat in the diet may cause dryness of the skin. It is necessary to analyse and fulfill labeling and compositional requirements.

ACID-INSOLUBLE ASH

Acid-insoluble ash is a measure of the surface contamination of fruits, vegetables and spices, wheat and rice coating. It is usually the sandy matter contamination. In Zambia, surface contamination of agricultural products is encountered during harvesting, drying and storage.The sandy matter determination is an important

parameter for sun dried vegetables in Zambia. This is so because the vegetables are often exposed to wind and sand contamination during the drying process. The results for sandy matter determination are as recorded in tables (1-5). Care should be taken in the cleaning and handling of vegetables prior to drying as to minimize sandy matter contamination.

VITAMIN A

Vitamin A is a fat soluble vitamin hence fat is required for its absorption and is essential in the diet. It is important for vision, formation and maintenance of skin. Lack of vitamin A in the diet causes night blindness, severe eye sores, reduced resistance to infection in children and retarded growth and development in children. Vitamin A deficiency can be prevented by consumption of dark green leafy vegetables such as pumpkin, bean and cowpea leaves. Also consumption of milk,fish,carrots,mangoes etc (Javaheri et al,1997).

Results obtained for vitamin A are as shown in the tables (1-5). The values for vitamin A obtained were pumpkin leaves had 0.173µg/ml, cowpea leaves had 0.094µg/ml, lunkomba had 0.178µg/ml, cabbage had 0.085µg/ml and rape had 0.183µg/ml. The low results could be due to the loss of the colour pigments, carotene during the drying process.

FIBRE

Dietary fibre can be defined as polysaccharides and lignin that are indigestible by mammalian enzymes (Nielsen, 1998). The major components of dietary fibre are

cellulose, hemicellulose, pectin, lignin, and hydrocolloids, which include gums. The U S Daily Reference Value for dietary fibre has been set at 25g per 2000kcal to promote optimal health (Nielsen, 1998).

In the diet fibre plays an important role in that it provides bulk for peristaltic action and facilitates the passage of material through the bowel. The improved bowel movements cause more rapid removal of unabsorbed breakdown products, which otherwise cause stomach irritation and perhaps encourage conditions conducive for the development of cancer. Good sources of fibre include fruit, vegetables, foods rich in starch like sweet potatoes, cassava and whole products. Crude fibre determined in the dry vegetables was in the range of 5.5% to 11.5% as is shown in the tables (1-5). Vegetables are some of the foods of good fibre source.

AFLATOXINS

Aflatoxins are produced by *Aspergillus flavus* and *Aspergillus parasiticus*. These moulds are found in subtropics and tropical areas. They are acutely toxic as well as carcinogenic. They are found in many agricultural products especially groundnuts and maize (Adams & Moss, 2000). Aflatoxins are particularly a problem where high humidity and warm temperatures are prevalent as these encourage their highest production in stored products.

WHO standards for aflatoxin is 30μkg, while the FAO standard is 50μg and the EU standard is <5ppm. Some countries have set lower standards than FAO & WHO.

Aflatoxins were determined as shown in the tables (1-5). Aflatoxins were detected in dried lunkomba leaves at very low levels of $1x10^{-5}g$ in 0.02ml as compared to the WHO, FAO and EU standards. This means that consumption of lunkomba would not cause adverse effects to ones health.

Table 1. Dried Pumpkin Leaves

PARAMETER	STORED AT 25°C
Moisture	11.62%
Protein	0.352%
Fat	2.60%
Acid-Insoluble Ash	5.20%
Vitamin A	0.173µg/ml
Fibre	9.52%
Aflatoxin	N.D

Table 2. Dried Cowpea Leaves

Parameter	**Stored at 25°C**
Moisture	12.51%
Protein	0.323%
Fat	4.46%
Acid-Insoluble Ash	2.09%
Vitamin A	0.094µg/ml
Fibre	10.20%
Aflatoxin	N.D

Table 3. Dried Lunkomba (Delele)

Parameter	Stored at 25°C
Moisture	8.98%
Protein	0.196%
Fat	1.73%
Acid-Insoluble Ash	6.88%
Vitamin A	0.178μg/ml
Fibre	5.50%
Aflatoxin	$1\times10^{-}5$g in 0.02ml

Table 4. Dried Cabbage

Parameter	Stored at 25°C
Moisture	13.65%
Protein	0.16%
Fat	2.30%
Acid-Insoluble Ash	3.25%
Vitamin A	0.085μg/ml
Fibre	10.50%
Aflatoxin	ND

Table 5. Dried Rape

Parameter	Stored at 25°C
Moisture	9.38%
Protein	0.25%
Fat	2.54%
Acid-Insoluble Ash	1.50%
Vitamin A	0.183μg/ml
Fibre	11.50%
Aflatoxin	ND

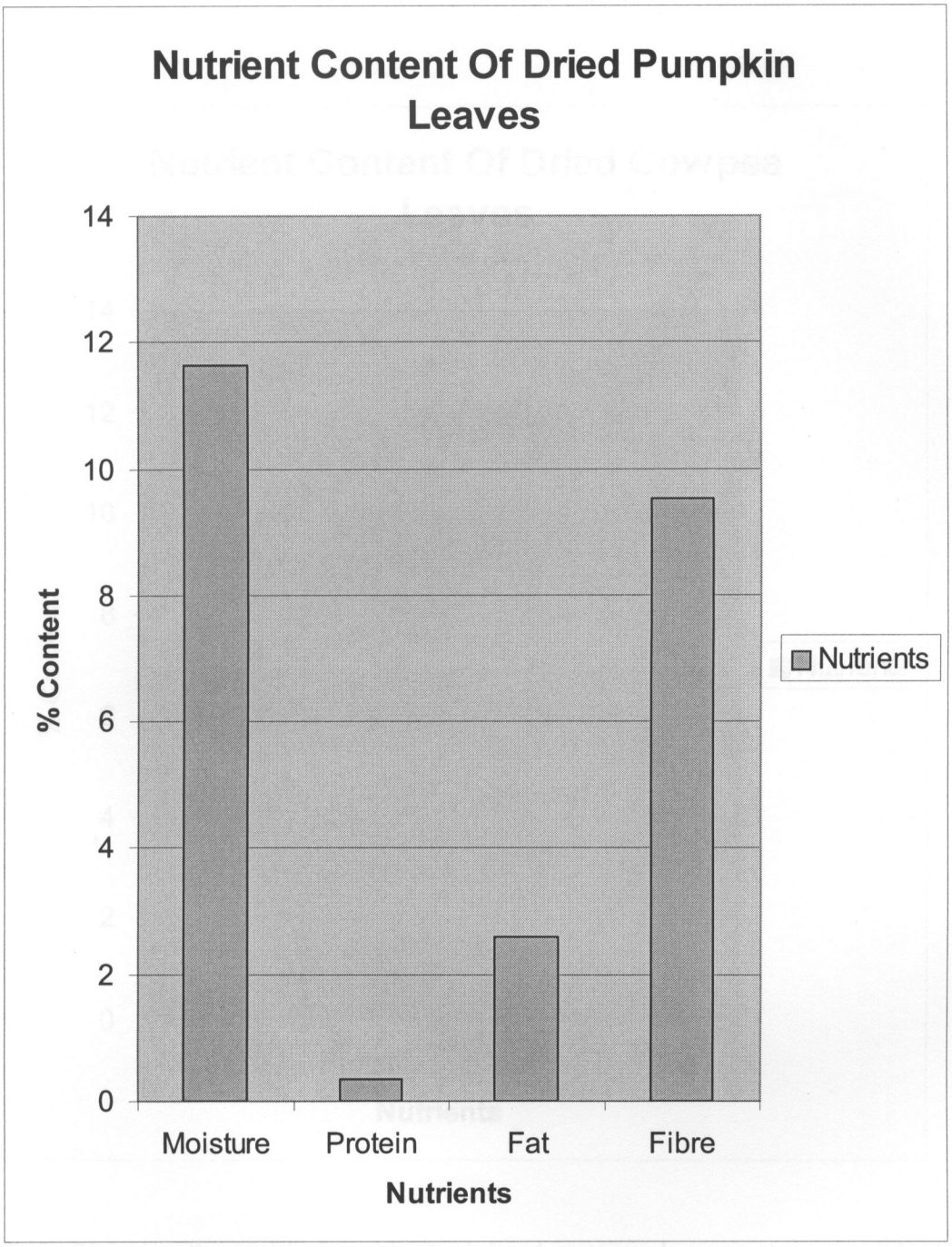

Fig 1: Showing the nutrient content of dried pumpkin leaves stored at 25°C

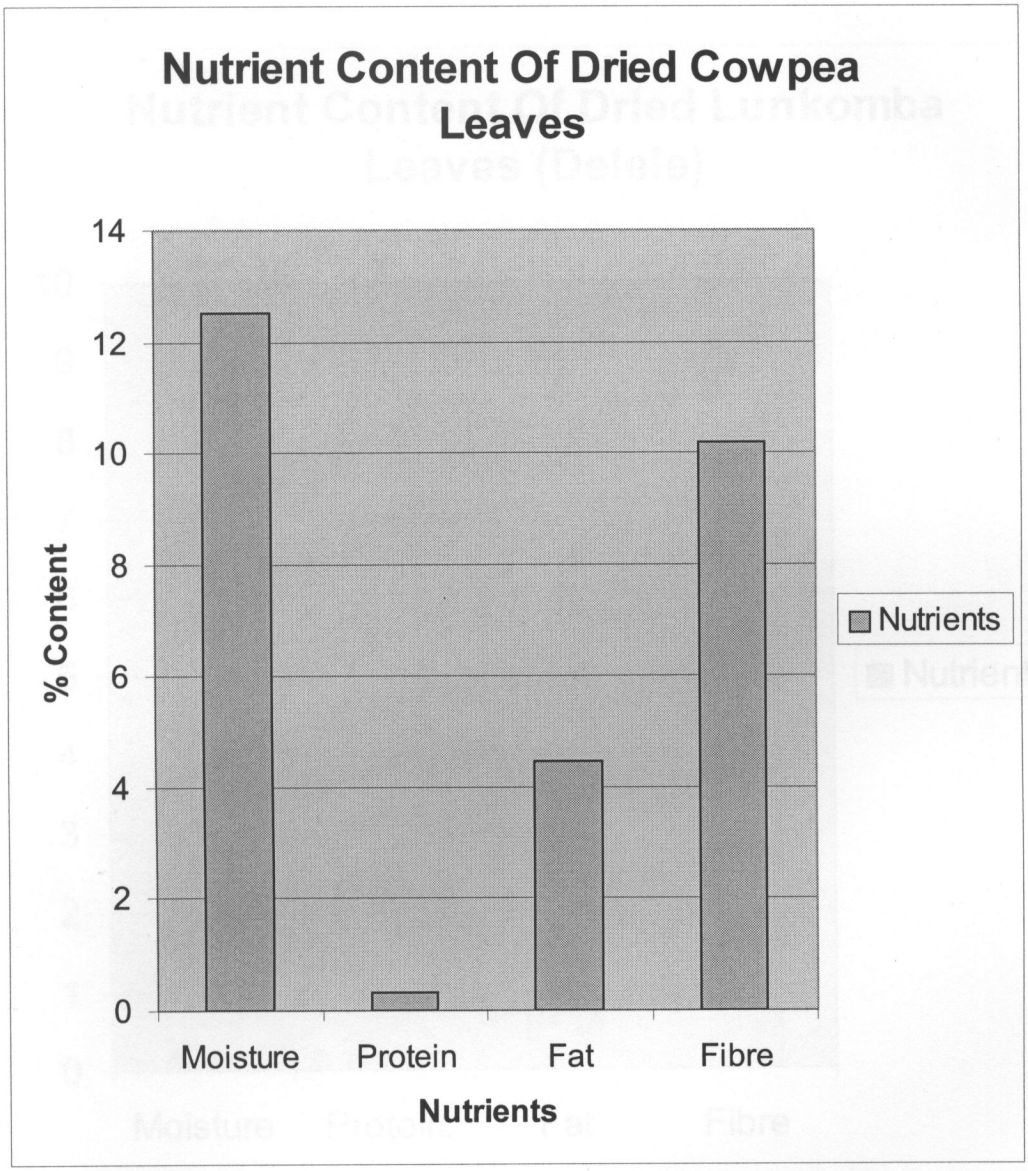

Fig2: Showing the nutrient content of dried cowpea leaves stored at 25°C.

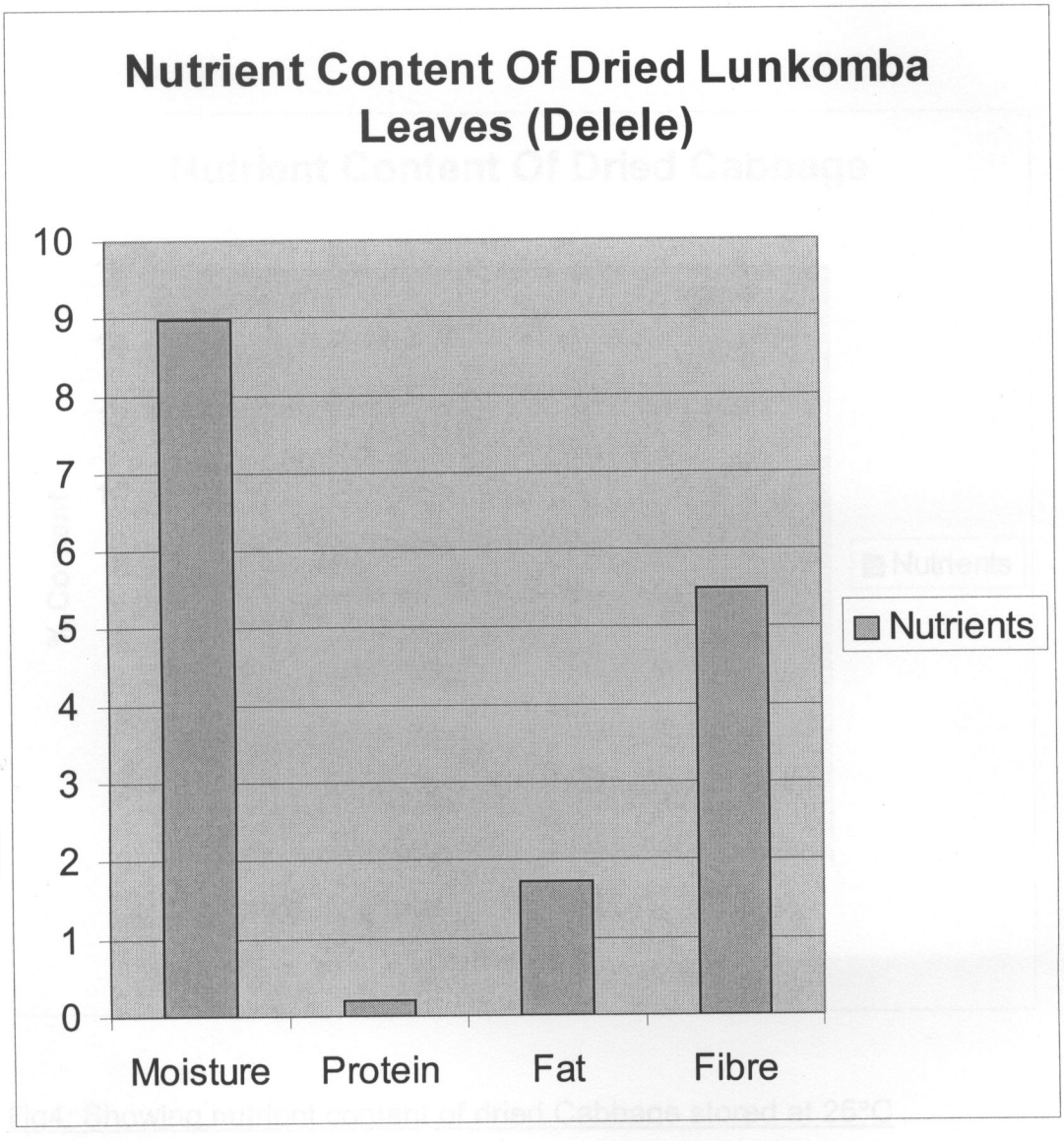

Fig3: Showing nutrient content of dried Lunkomba Leaves (Delele) stored at 25°C

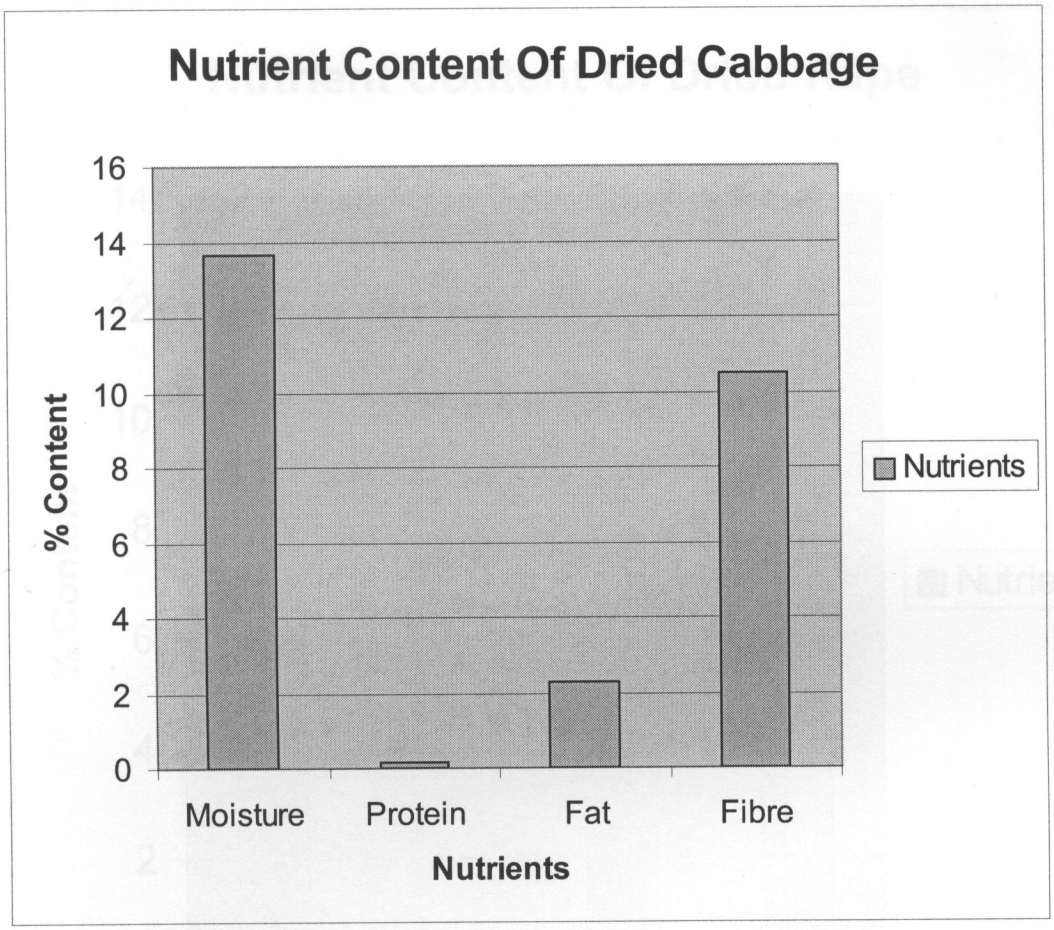

Fig4: Showing nutrient content of dried Cabbage stored at 25°C

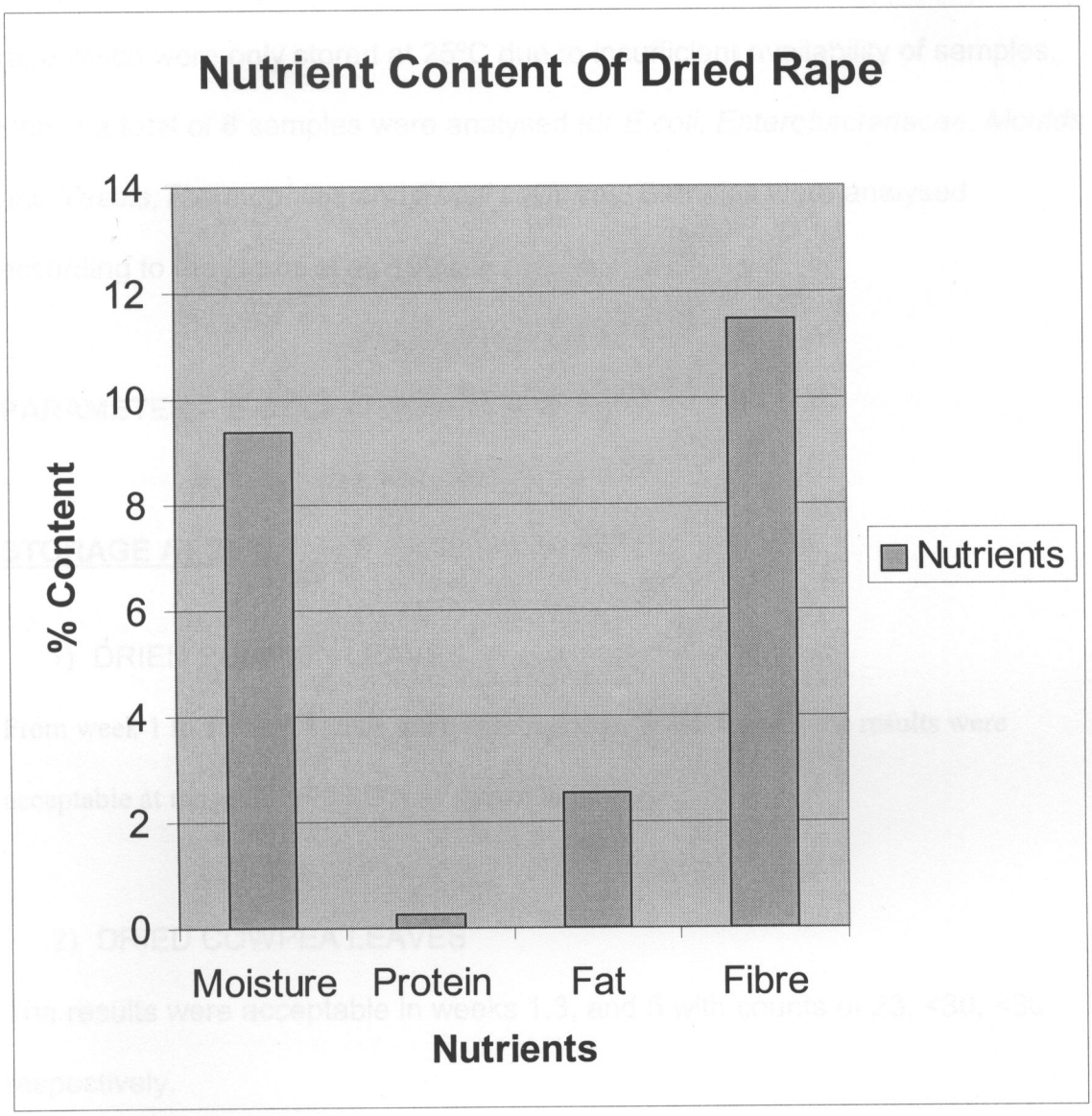

Fig5: Showing nutrient content of dried Rape stored at 25°C

7.2 MICROBIOLOGICAL ANALYSIS

The 5 dried vegetable samples were stored at two temperatures of 25 and 45°C. Samples were analysed at both storage temperatures except for cabbage and rape which were only stored at 25°C due to insufficient availability of samples. Hence a total of 8 samples were analysed for *E.coli, Enterobacteriacae, Moulds* and *Yeasts, Thermophiles* and *Fecal coliforms*. Samples were analysed according to the Nguzi et al, 1999.

PARAMETER – *E.COLI*

STORAGE AT 25°C

1) DRIED PUMPKIN LEAVES

From week 1 to 3 *E.coli* counts were unacceptable. Week 4 and 5 the results were acceptable at range 30 – 70 MPN,as shown in table 6.

2) DRIED COWPEA LEAVES

The results were acceptable in weeks 1,3, and 5 with counts of 23, <30, <30 respectively.

Unsatisfactory results were in weeks 2 and 4 with counts of >11000 and 200 respectively. Results as shown in table 8.

3) DRIED LUNKOMBA LEAVES

In weeks 1, 3, 5 the results were acceptable. While in weeks 2 and 4 results were unsatisfactory as shown in table

4) DRIED CABBAGE

Counts were acceptable in all weeks. They were in the range of <30 – 40 MPN.

5) DRIED RAPE

In weeks 1,2,3, 5 counts were acceptable, while in week 4 counts were unsatisfactory with counts of 2100 MPN.

STORAGE AT 45°C

1) DRIED PUMPKIN LEAVES

Results were acceptable in weeks 1,3, 4 & 5 as is shown in table 7.

Week 2 showed unsatisfactory results with counts of >11000 MPN.

2) DRIED COWPEA LEAVES

Acceptable results were found in weeks 3,4,5 with counts of <30 which were good results.Unsatisfactory results were in weeks 1 and 2 as is seen in table 9.

3) DRIED LUNKOMBA LEAVES

Acceptable results were in weeks 1,3 and 5. While in weeks 2 and 4 they were unacceptable. This is shown in table 11.

PARAMETER – *ENTEROBACTERIACAE*

STORAGE AT 25°C

1) DRIED PUMPKIN LEAVES

Acceptable results were in weeks 2,4 and 5.

Unsatisfactory results were in weeks 1 and 3 with counts of $1.0x10^5$cfu/g and $2.9x10^5$cfu/g respectively, as shown in table 6.

2) DRIED COWPEA LEAVES

Acceptable results were in weeks 1,4 and 5. Counts are as shown in table 8.

Unsatisfactory results were in weeks 2 and 3 with counts of $2.0x10^5$ and $1.1x10^7$ cfu/g respectively.

3) DRIED LUNKOMBA LEAVES

Acceptable results were in weeks 1,2,4 and 5 shown in table 10.

Unsatisfactory results were only found in week 3 with counts of $1.0x10^5$ cfu/g.

4) DRIED CABBAGE

Acceptable results were in weeks 2,3,4 and 5 shown in table12.

Unsatisfactory results were only in the 1st week with counts of $7.5x10^4$ cfu/g.

5) DRIED RAPE

Results were unsatisfactory from weeks 1 – 5. This showed that dried rape stored at 25°C, has high counts of enterobacteriacae, which affects its storage life.

STORAGE AT 45°C

1) DRIED PUMPKIN LEAVES

Acceptable results in weeks 1,4 and 5 as shown in table 7.

Unsatisfactory results were in weeks 2 and 3 with counts of $1.1x10^5$ and $9.5x10^4$ cfu/g respectively.

2) DRIED COWPEA LEAVES

Acceptable results were in weeks 1,4 and 5 as shown in table 9.

Unsatisfactory results were in weeks 2 and 3 with counts of $1.4x10^5$ and $7.5x10^4$ cfu/g respectively.

3) DRIED LUNKOMBA LEAVES

Results were acceptable in all the weeks of analysis. This showed that storage of dried Lunkomba at 45°C is not affected by *enterobacteriacae spp*. Results are shown in table 11.

PARAMETER – *YEASTS AND MOULDS*

Analysis of *Yeasts and Moulds* was limited to the 1st week only and it was only done on dried pumpkin leaves, dried cowpea leaves and lunkomba leaves due to insufficient supplement in the laboratory.

STORAGE AT 25°C

1) DRIED PUMPKIN LEAVES

Results were very satisfactory at counts of $1.0x10^3$ in the 1st week.

2) DRIED COWPEA LEAVES

Results were satisfactory at $6.1x10^2$ cfu/g as shown in table 8.

3) DRIED LUNKOMBA LEAVES

Satisfactory results were obtained at counts of $6.8x10^2$ cfu/g as shown in table 10.

STORAGE AT 45°C

1) DRIED PUMPKIN LEAVES

Satisfactory results with counts of $7.2x10^2$ cfu/g as shown in table 7.

2) DRIED COWPEA LEAVES

Acceptable results at counts of $1.4x10^4$ cfu/g shown in table 9.

3) DRIED LUNKOMBA LEAVES

Acceptable results at counts of $1.9x10^3$ cfu/g shown in table 11.

PARAMETER – *THERMOPHILES*

STORAGE AT 25°C

1) DRIED PUMPKIN LEAVES

Acceptable results in weeks 1,3 and 5 shown in table 6.

Unsatisfactory results in weeks 2 and 4 with counts of $1.1x10^6$ and $1.7x10^6$ cfu/g respectively.

2) DRIED COWPEA LEAVES

Acceptable results in weeks 1,2 and 4 as shown in table 8.

Unsatisfactory results in weeks 3 and 5.

3) DRIED LUNKOMBA LEAVES

Results in all the weeks were acceptable with week 5 being satisfactory, as shown in table10.

4) DRIED CABBAGE

Results in all the weeks were satisfactory as shown in table 12.

5) DRIED RAPE

Results were acceptable in all weeks as shown in table 13.

STORAGE AT 45°C

1) DRIED PUMPKIN LEAVES

Results in all weeks were acceptable as shown in table 7.

2) DRIED COWPEA LEAVES

Acceptable results in weeks 1 and 2 as shown in table 9.

Unsatisfactory results in weeks 3,4 and 5.

3) DRIED LUNKOMBA LEAVES

All weeks had acceptable results with week 2 having satisfactory results with counts of $1.8x10^3$ cfu/g. This is shown in table 11.

PARAMETER – *FECAL COLIFORMS*

STORAGE AT 25°C

1) DRIED PUMPKIN LEAVES

Fecal coliforms were detected in weeks 1,2 and 3. They were not detected in week 4 and 5.

2) DRIED COWPEA LEAVES

Fecal coliforms were detected in weeks 1,2,4 and 5. They were not detected in week 3 only.

3) DRIED LUNKOMBA LEAVES

Coliforms were detected in all weeks as shown in table 10.

4) DRIED CABBAGE

Fecal coliforms were detected from week 1 to 4 and not detected in week 5. This is shown in table 12.

5) DRIED RAPE

Fecal coliforms were detected in weeks 1,2 and 3. They were not detected in weeks 4 and 5.

STORAGE AT 45°C

1) DRIED PUMPKIN LEAVES

Fecal coliforms were detected in weeks 1,2 and 3. They were not detected in weeks 4 and 5, as shown in table 7.

2) DRIED COWPEA LEAVES

Fecal coliforms were detected in all the weeks from week 1 to 5. This is shown in table 9.

3) DRIED LUNKOMBA LEAVES

Fecal coliforms were detected in weeks 1,2 4 and 5. They were not detected in the 3rd week. This is shown in table 11.

Table 6. Dried Pumpkin Leaves Stored At 25°C

Name Of Micro-Organism	Week				
	1	2	3	4	5
E. Coli	>1100**	11000^{***}	750^{***}	70^{**}	$<30^{**}$
Enterobacteriacae	$1.0x10^{5***}$	$5.0x10^{4**}$	$2.9x10^{5***}$	$1.6x10^{4**}$	$4.5x10^{4**}$
Moulds & Yeasts	$1.0x10^{3*}$				
Thermophiles	$2.4x10^{5**}$	$1.1x10^{6***}$	$6.0x10^{4**}$	$1.7x10^{6***}$	$8.1x10^{4**}$
Fecal coliforms	D	D	D	ND	ND

Table 7. Dried Pumpkin Leaves Stored At 45°C

Name Of Micro-Organism	Week				
	1	2	3	4	5
E. Coli	9^{*}	$>11000^{***}$	$<30^{**}$	110^{**}	$<30^{**}$
Enterobacteriacae	$4.3x10^{4**}$	$1.1x10^{5***}$	$9.5x10^{4***}$	$4.1x10^{3**}$	$6.7x10^{3**}$
Moulds & Yeasts	$7.2x10^{2*}$				
Thermophiles	-	$3.4x10^{5**}$	$2.0x10^{4**}$	$2.9x10^{5**}$	$5.7x10^{5**}$
Fecal coliforms	D	D	D	ND	ND

D = Detected
ND = Not Detected
* Satisfactory
** Acceptable
*** Unsatisfactory

Table 8. Dried Cowpea Leaves Stored at 25°C

Name Of Micro-Organism	Week				
	1	2	3	4	5
E. Coli	23^{*}	$>11000^{***}$	$<30^{**}$	200^{***}	$<30^{**}$
Enterobacteriacae	$6.7x10^{3**}$	$2.0x10^{5***}$	$1.1x10^{7***}$	$1.6x10^{4**}$	$4.8x10^{3**}$
Moulds & Yeasts	$6.1x10^{2*}$				
Thermophiles	$4.5x10^{4**}$	$4.2x10^{4**}$	$2.3x10^{6***}$	$3.8x10^{4**}$	$8.5x10^{6***}$
Fecal coliforms	D	D	ND	D	D

Table 9. Dried Cowpea Leaves Stored at 45°C

Name Of Micro-Organism	Week				
	1	2	3	4	5
E. Coli	1100^{***}	2400^{***}	$<30^{**}$	$<30^{**}$	$<30^{**}$
Enterobacteriacae	$1.9x10^{3**}$	$1.4x10^{5***}$	$7.5x10^{4***}$	$1.4x10^{4**}$	$2.3x10^{4**}$
Moulds & Yeasts	$1.4x10^{4**}$				
Thermophiles	$2.2x10^{5**}$	$2.1x10^{5**}$	$1.0x10^{6***}$	$1.5x10^{6***}$	$1.8x10^{6***}$
Fecal coliforms	D	D	D	D	D

D = Detected
ND = Not Detected
* Satisfactory
** Acceptable
*** Unsatisfactory

Table 10. Dried Lunkomba (Delele) Stored At 25°C

Name Of Micro-Organism	Week				
	1	2	3	4	5
E. Coli	>1100**	11000***	40**	210***	<30**
Enterobacteriacae	$6.3x10^{3**}$	$1.2x10^{4**}$	$1.0x10^{5***}$	$2.2x10^{4**}$	$2.8x10^{4**}$
Moulds & Yeasts	$6.8x10^{2*}$				
Thermophiles	$8.9x10^{3**}$	$6.1x10^{4**}$	$2.1x10^{5**}$	$2.0x10^{4**}$	$1.9x10^{3*}$
Fecal coliforms	ND	D	ND	ND	ND

Table 11. Dried Lunkomba (Delele) Stored At 45°C

Name Of Micro-Organism	Week				
	1	2	3	4	5
E. Coli	4*	4600***	<30**	210***	<30**
Enterobacteriacae	$5.9x10^{4***}$	$2.0x10^{5**}$	$4.2x10^{4**}$	$7.2x10^{3**}$	$1.8x10^{4**}$
Moulds & Yeasts	$1.9x10^{3**}$				
Thermophiles	$1.1x10^{4**}$	$1.8x10^{3*}$	$1.5x10^{4**}$	$1.5x10^{4**}$	$1.8x10^{5**}$
Fecal coliforms	D	D	ND	D	D

D = Detected
ND = Not Detected
* Satisfactory
** Acceptable
*** Unsatisfactory

Table 12. Dried Cabbage Stored At 25°C

Name Of Micro-Organism	Week				
	1	2	3	4	5
E. Coli	<30**	<30**	<30**	40**	<30**
Enterobacteriacae	$7.5x10^{4***}$	$5.0x10^{4**}$	$4.1x10^{4**}$	$4.5x10^{3**}$	$2.7x10^{2**}$
Moulds & Yeasts	-	-	-	-	-
Thermophiles	$4.0x10^{4**}$	$2.0x10^{4**}$	$1.8x10^{3*}$	$1.9x10^{3*}$	$4.2x10^{2*}$
Fecal coliforms	D	D	D	D	ND

Table 13. Dried Rape Stored At 25°C

Name Of Micro-Organism	Week				
	1	2	3	4	5
E. Coli	<30**	<30**	70**	2100+***	30+**
Enterobacteriacae	$5.7x10^{5***}$	$2.0x10^{5***}$	$2.9x10^{5***}$	$1.4x10^{5***}$	$8.0x10^{5***}$
Moulds & Yeasts	-	-	-	-	-
Thermophiles	$8.1x10^{4**}$	$4.0x10^{4**}$	$4.0x10^{4**}$	$2.0x10^{5**}$	$1.0x10^{5**}$
Fecal coliforms	D	D	D	ND	ND

D = Detected
ND = Not Detected
* Satisfactory
** Acceptable
*** Unsatisfactory

7.3 STATISTICAL ANALYSIS

NULL HYPOTHESIS:

There is no significant difference between the specific microbial counts during storage at 25°C and 45°C.

STATISTICAL TABLE OF PUMPKIN LEAVES AT 95% CONFIDENCE LEVEL

Enterobacteriacae									
Temp.	$\bar{X}$	$\bar{X}..$	$(\bar{X} - \bar{X}.)^2$	S^2	S^2_{pooled}	$S^{2\ sample}_{means}$	F_{cal}	F_{tab}	Significance
25°C	4.82	4.6	0.04	0.48	0.57	0.40	0.70	6.61	no
45°C	4.4		0.04	0.66					
			E=0.08						
Thermophiles									
25°C	5.47	4.84	0.39	0.65	1.53	3.90	2.55	6.61	no
45°C	4.21		0.39	2.42					
			E=0.78						

$\bar{X}$ = Mean of samples

$\bar{X}..$ = Mean of Means

S^2 = Variance

E = sum of squared standard deviation

n = Number of samples which was 2 (storage at the two temperatures)

r = Number of variates which was 5

STATISTICAL TABLE OF COWPEA LEAVES AT 95% CONFIDENCE LEVEL

Enterobacteriacae									
Temp.	$\bar{X}$	$\bar{X}..$	$(\bar{X} - \bar{X}.)^2$	S^2	S^2_{pooled}	S^2 sample means	F_{cal}	F_{tab}	Significance
25°C	4.81	4.59	0.05	1.40	1.06	0.5	0.47	6.61	no
45°C	4.36		0.05	0.72					
			E=0.1						
Thermophiles									
25°C	5.43	5.63	0.04	1.13	0.79	0.4	0.51	6.61	no
45°C	5.82		0.04	0.45					
			E=0.08						

STATISTICAL TABLE OF LUNKOMBA LEAVES AT 95% CONFIDENCE LEVEL

Enterobacteriacae									
Temp.	$\bar{X}$	$\bar{X}..$	$(\bar{X} - \bar{X}.)^2$	S^2	S^2_{pooled}	S^2 sample means	F_{cal}	F_{tab}	Significance
25°C	4.33	4.44	0.01	0.45	0.49	0.1	0.20	6.61	no
45°C	4.56		0.01	0.54					
			E=0.02						
Thermophiles									
25°C	4.33	4.25	0.0064	0.78	0.74	0.05	0.07	6.61	no
45°C	4.18		0.0049	0.71					
			E=0.01						

8.0 CONCLUSION

Chemical analysis showed the levels of nutrient content in the dried vegetables analysed which were pumpkin leaves, cowpea leaves, lunkomba leaves, cabbage and rape. Very minimal documentation has been done on the nutrient content of most traditional and horticultural dried vegetables. Knowledge of nutrient content enables some consumers to have an informed choice when deciding to purchase certain foods. Nutrient information is a labeling requirement under the Codex Alimentarius Commission.

The samples in this analysis were only analysed within 5 weeks when they were brought and after being stored at 25°C. The study of these products for a longer period can give indications of how stable these products are in terms of nutrient content.

A longer period of study would help the processor improve on both the processing and storage techniques of dried vegetables. The information would also be vital in designing a marketing strategy for their products. The information will also be important in selecting packaging materials suitable for dried vegetables. The moisture and nutrient content were identified.

Microbial analysis showed that some dried vegetable products do meet the PHLS (2000) and WHO/FAO (1992) Tables 6-13 depict products that meet the guidelines and those that do not meet the guidelines. Statistically it was shown that there is no significance difference in the microbial counts of the vegetables stored at both 25°C and 45°C.

Microorganisms isolated and identified include *coliforms, enterobacteriaceae, thermophiles, moulds and yeasts, e.coli* and *fecal coliforms.* Some of the microbial criteria were above acceptable levels as is shown in tables 6-13. These results can be used as criteria for rejection condemnation acceptance of the dried vegetables products. Furthermore the results can form a basis for improving the processing and storage practices. This can lead to the improvement of product quality, since the prevalent microorganisms have been identified.

9.0 RECOMMENDATIONS

The chemical analysis was carried out over a period of less than 5 weeks. To ascertain how dried vegetables can be stored for a longer time, extended shelf life studies which will take into account the weather pattern changes is very crucial. Other quality parameters can be included in the analysis to ensure that the products crucial quality characteristics are extensively studied and understood by all the people involved in the processing of the dried vegetables. That way quality of the products can be guaranteed as the quality parameters would have been studied thoroughly.

The microbiological studies were carried out for a period of 5 weeks. The results obtained for the period under study do not show conclusively the shelf life of the dried vegetables because the 5 weeks was too short to establish the optimum storage time. The results do not give information as to when the products begin to expire. The 5 weeks period was not sufficient to observe and analyse any

exceptionally high counts of microorganisms associated with expiry of dried vegetables.

The results are very useful in that they can be used as a guideline on how to handle and process the products in the way that microbial contamination is minimized.

The period of study should be extended to 2 – 3 years to thoroughly conclude that these dried vegetables can withstand extended period before becoming unfit for human consumption or marketing.

The following points will show were this study and processing of dried vegetables needs to be improved:

- The amounts of dried vegetable samples to be analysed should be increased so that the same products are studied over a longer period of time to ensure that relisble outcomes are achieved.
- The study period should be increased to about 2 – 3 years. This study period can give vital information on processing techniques, and storage practices. Information obtained can be useful in devising better ways of processing, consumption, storage and marketing of dried vegetables. This study can also be done using accelerated methods and hence extrapolating the results to a required period of time of study.
- Care when handling the vegetables by the processor should be looked into in order to reduce on the fecal contamination and hence rendering a better count of coliforms. Therefore educating the processor on self

hygiene and good manufacturing practices would greatly reduce on the microbial load in dried vegetables.

- The processor should be educated on the effects of extended blanching in that it could have affected some nutrient results which were obtained as well as drying the vegetables in direct sunlight.
- Processing of dried vegetables should be done carefully in order to avoid sandy matter contamination.
- Packaging studies in relation to products, packaging material, water activity, temperature and microbial control can help improve the quality and utilization of products.
- Water quality, the portability of water used in processing should be checked against World Health Organisation Standards and the Food and Drug Regulations of the Food Laws of Zambia.
- The amount of sandy matter can be reduced by better processing and handling during drying of the vegetables as well as ensuring the removal of soil and sand during harvesting.

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APPENDIX

TABLE 5 GUIDELINES FOR THE MICROBIOLOGICAL QUALITY OF VARIOUS READY-TO-EAT FOODS

Food category	Criterion	Microbiological quality(CFU per gram unless stated)			
		Satisfactory	Acceptable	Unsatisfactory	Unacceptable/potentially hazardous*
	Aerobic colony count[1] 30°C/48h				
1					
2		$< 10^{3}$	$10^{3} - < 10^{4}$	$\geq 10^{4}$	N/A
3		$< 10^{4}$	$10^{4} - < 10^{5}$	$\geq 10^{5}$	N/A
4		$< 10^{5}$	$10^{5} - < 10^{6}$	$\geq 10^{6}$	N/A
5		$< 10^{6}$	$10^{6} - < 10^{7}$	$\geq 10^{7}$	N/A
		N/A	N/A	N/A	N/A
	Indicator organisms[2]				
1--5	*Enterobacteriacae*[3]	<100	$100 - < 10^{4}$	$\geq 10^{4}$	N/A
1--5	*E.Coli* (total)	<20	20-<100	≥ 100	N/A
1--5	Listeria spp (total)	<20	20-<100	≥ 100	N/A
1--5	**Pathegens**				
1--5	salmonella spp	not detected in 25g			not detected in 25g
1--5	Campylobacter spp	not detected in 25g			not detected in 25g
1--5	*E.coli* O 157 & other VTEC	not detected in 25g			not detected in 25g
1--5	V.cholerae	not detected in 25g			not detected in 25g
1--5	V.parahaemolyticus[a]	< 20	20-<100	100-$<10^{3}$	≥ 10^{3}
1--5	L.monocytogenes	< 20**	20-<100	N/A	≥ 100
1--5	S.aureus	< 20	20-<100	$100 - < 10^{4}$	$\geq 10^{4}$
1--5	C.perfringes	< 20	20-<100	$100 - < 10^{4}$	$\geq 10^{4}$
1--5	B.cereus and other pathogenic				
1--5	Bacillus spp#	< 10^{3}	$10^{3} - < 10^{4}$	$10^{4} - < 10^{5}$	$\geq 10^{5}$

*Prosecution based solely on high colony counts and/or indicator organism in the absence of other criteria of unacceptability is unlikely to be successful.

[1]Guidelines for aerobic colony counts not apply to certain fermented foods - salami,soft cheese, and unpasteurised yoghurt.These foods fall in the category 5. Acceptability is based on appearance ,smell, texture, and the levels or absence of organisms or pathogens.

[2] On occasions some strains may be pathogenic.

[3] Not applicable to fresh fruit ,vegetables and salad vegetables.

[a] Relevant to seafood only.

If the Bacillus counts exceed 10 000 CFU/g, the organism should be identified.

PHLS guidelines (2001)

** Not detected in 25g for certain long shelf-life products under refrigeration
NA Not applicable

TABLE 5 CONTINUED

GRADES FOR MICROBIOLOGICAL QUALITY

The terms used to express the microbiological quality of ready-to-eat foods are:

i **Satisfactory** - test results indicating good microbiological quality.
ii **Acceptable** - an index reflecting a borderline limit of microbiological quality.
iii **Unsatisfactory** - test results indicating that further sampling may be necessary and that environmental health officers may wish to undertake a further inspection of the premises concerned to determine whether hygiene practices for food production or handling are adequate or not
iv **Unacceptable/potentially hazardous** - test results indicating that urgent attention is needed to locate the source of the problem; a detailed risk assessment is recommended. Such results may also form a basis for prosecution by environmental health departments, especially if they occur in more than one sample. Food examiners will wish to draw on their own experience and expertise in determining the advice and comments they wish to give and they will be required to do this if invited to give an expart opinion during legal proceedings

PHLS guidelines (2001)