

DEVELOPMENT OF COWPEA-FORTIFIED WEANING FOOD; CONSUMER
EXPECTATIONS, FUNCTIONAL AND CHEMICAL PROPERTIES

BY

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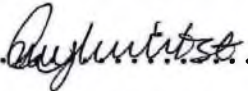
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DEDICATION

To MAMA and DADDY
I could not have made it
this far without either
of you

ABSTRACT

Questionnaires were administered to a hundred and thirty-two mothers (132) selected at random at four (4) mother and child welfare clinics in Accra in order to obtain their views and expectations of cowpea-fortified weaning formulations. Majority of these mothers (>80%) prepared infant weaning porridges from raw ingredients, eg. fermented maize dough, and were willing to incorporate cowpea into their infant porridges and other foods if it was available as a raw or pre-cooked flour on the market. Factors that motivated the mothers in the selection of an infant weaning food included the cost and nutritional value of the product. The child's acceptance of the food, usually maintained its continued use.

Germinated cereal flours (of maize, millet and sorghum) were added to 3-day fermented maize dough in attempt to degrade the starch by the action of alpha and beta- amylases in the cereal malt and thereby reduce its bulk density. The cereals were sprouted for 2,3 and 4 days and then incorporated into fermented maize dough at concentrations of 5% and 10% (dry matter basis). Sorghum malt in comparison to millet and maize malts was not effective in terms of lowering the hot and cold paste viscosities of the fermented maize dough. Millet and maize malts liquified the dough considerably. The effect of 4-day sprouted cereal malt was most pronounced whilst the optimum

activity of maize malt observed after three days of sprouting.

The effects of maize dough fermentation and its fortification with steamed cowpea on proximate as well as oligosaccharide composition, physicochemical and functional characteristics were also studied. A 5x4x2x2 factorial experiment with cowpea level (0, 5, 10, 15, 20 %), fermentation time (0, 24, 48 72 h), fermentation method (single-component and multi-component) and cowpea steaming time (0, 4 min) as the variables was performed. The cowpeas were dehulled, steamed, dried at 65 °C for 24 h and milled into flour. Maize was soaked in water (18 h), drained and milled into flour. The maize-cowpea blends were made into a 50% moisture dough, fermented for the specified periods, dried at 65°C and milled into flour. Moisture, protein, ash and fat content were measured . Stachyose, raffinose and other sugars were extracted from the samples and analyzed using High Pressure Liquid Chromatography (HPLC) .

The protein content of the maize-cowpea blends increased with level of cowpea in the blend; the ash and fat contents were not influenced by process variables. The pH of the samples were affected by fermentation time, steaming and the level of cowpeas in the blend. Cowpeas was the main source of sucrose, stachyose and raffinose and maize the source of glucose/galactose. Fermentation caused a reduction in stachyose and

glucose/galactose. The mixing of cowpea flour with fermented maize dough prior to drying (single component fermentation) gave similar effects on sugar concentrations as detected in the co-fermented samples (multi-component fermentation).

Fermentation can therefore reduce anti-nutritional factors and non-digestible components in legumes. The process can be used to develop acceptable weaning foods from maize-cowpea blends.

Models were developed to predict Brabender viscosity from Brookfield viscosity determined at various spindle speeds (10, 20, 50rpm), solids concentration of samples and temperatures. R^2 of the models could explain 95.32% - 98.32% of the variation observed. There was high correlation ($R = 84.51\% - 95.97\%$) between the viscosity measurements made by both instruments.

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MAY GOD RICHLY BLESS YOU !

TABLE OF CONTENTS

	PAGE
DECLARATION.....	i
DEDICATION.....	ii
ABSTRACT.....	iii
ACKNOWLEDGEMENT.....	vi
TABLE OF CONTENTS.....	vii
LIST OF FIGURES.....	xi
LIST OF TABLES.....	xiii
INTRODUCTION.....	1
1.1 The weaning period - a crucial period in the life of an infant.....	1
1.2 The shortcomings of traditional weaning diets....	2
1.3 Weaning food formulation.....	3
1.4 Main objectives.....	4
LITERATURE REVIEW.....	6
2.1 The characteristics of a weaning food.....	6
2.2 The requirements of a weaning food.....	8
2.3 The development of weaning foods.....	9
2.4 Traditional food technologies and infant feeding.....	10
2.4.1 Germination.....	11
2.4.2 Fermentation.....	12
2.5 The choice of cowpea as a fortification agent.....	13
2.6 Functional and chemical properties of weaning foods.....	15

2.6.1	Functionality of cowpea-fortified preparations.....	17
2.7	The benefits of consumer inputs in product development.....	19
MATERIALS AND METHODS.....		21
3.1	Materials.....	21
3.2	Methodology.....	21
3.2.1	Field Survey questionnaire administration.....	21
3.2.2	Laboratory Studies.....	22
3.2.2.1	To investigate the effect of the addition of cereal malt (sorghum, millet and maize) on the viscosity of cooked cereal based porridges	22
3.2.2.2	To investigate the effects of cowpea steaming and fermentation conditions on the proximate composition and the sugar concentration in maize-cowpea blends.....	25
3.2.2.3	Assesment of the Brookfield viscometer, a simple tool for measuring the viscosity of cooked gruels and to compare it to the Brabender viscoamylograph	28
3.2.3	Chemical analyses.....	29
3.2.3.1	Determination of mono-, di-, and oligosaccharides.....	29
3.2.3.2	Proximate analyses.....	29
3.2.3.3	Physico-chemical properties.....	30
3.2.3.3.1	pH and Acidity	30
3.2.3.4	Functional Properties.....	30
3.2.3.4.1	Water absorption.....	30
3.2.3.4.2	Cooked Paste viscosity	31

3.2.4	Data Analyses.....	32
RESULTS AND DISCUSSION		33
4.1	Mothers' perceptions of quality attributes in a cowpea based infant weaning food	33
4.1.1	Background data on respondents.....	33
4.1.2	The use of cowpeas in infant food preparation.....	39
4.1.3	Preferences indicated for various cereals in a cereal-legume blend.....	45
4.1.4	Cowpea Variety preferences indicated	48
4.1.5	Characteristics mothers preferred in infant food formulations	50
4.1.6	Sensory evaluation of some quality characteristics in weaning foods	54
4.2	Effect of cereal malt on the viscosity of fermented maize dough.....	56
4.2.1	Product description	56
4.2.2	Brabender Viscoamylograph viscosity indices	56
4.2.2.1	Pasting temperature.....	57
4.2.2.2	Peak Viscosity	58
4.2.2.3	Viscosity at 95°C	58
4.2.2.4	Viscosity at 95°C-HOLD	59
4.2.2.5	Viscosity at 50°C	61
4.2.2.6	Viscosity at 50°C-HOLD	65
4.2.3	Effect of cereal type on the pasting characteristics of fermented maize dough-cereal malt blend	67

4.3	The effects of cowpea steaming and fermentation on the chemical and functional properties of maize-cowpea blends	72
4.3.1	Product description	72
4.3.2	Product composition	72
4.3.3	pH and Acidity	72
4.3.4	Sugars and oligosaccharides	77
4.3.4.1	Cowpea	77
4.3.4.2	Maize	78
4.3.4.3	Fermented maize-cowpea blends	79
4.3.4.3.1	Co-fermentation.....	79
4.3.4.3.2	Blend after maize fermentation	83
4.3.5	Water absorption capacity	87
4.4	The use of Brookfield viscometer to measure the viscosity of cooked gruels and its comparison with the Brabender viscoamylograph	89
4.4.1	Apparent viscosity determined at 10 rpm	89
4.4.2	Apparent viscosity determined at 20 rpm	93
4.4.3	Apparent viscosity determined at 50 rpm	96
	CONCLUSION	99
	RECOMMENDATION	102
	REFERENCES	103
	APPENDICES	119

	LIST OF FIGURES	PAGE
Fig. 1	Fermented maize dough fortified with cereal malt .	23
Fig. 2	Maize-cowpea blends prepared for analyses.....	26
Fig. 3	Educational background of the respondents.....	34
Fig. 4	Number of children born to each respondent.....	38
Fig. 5	Foods prepared at home with the incorporation of cowpeas.....	40
Fig. 6	Foods proposed to be suitable for the incorporation of cowpea flour.....	43
Fig. 7	Preferences indicated for various cereals in a cereal-legume blend.....	46
Fig. 8	Cowpea variety preferences.....	49
Fig. 9	Colour preferences for infant foods.....	51
Fig. 10	Effect of sprouting time on the viscosity of fermented maize dough-cereal malt blends at 95°C-HOLD.....	60
Fig. 11	Effect of sprouting time on the viscosity of fermented maize dough-cereal malt blends at 50°C.....	62
Fig. 12	Effect of sprouting time in the viscosity of fermented maize dough-cereal malt blends at 50°C-HOLD.....	66
Fig. 13	The effect of sprouted sorghum on the pasting characteristics of 3-day fermented maize dough.....	68
Fig. 14	The effect of sprouted maize on the pasting characteristics of 3-day fermented maize dough.....	69
Fig. 15	The effect of sprouted millet on the pasting characteristics of 3-day fermented maize dough.....	70
Fig. 16	pH profiles: Effect of steam treatment and cowpea concentration on the traditional lactic acid.....	73

Fig. 17	Effect of addition of cowpeas on acid production during traditional lactic acid fermentation of maize dough.....	76
Fig. 18	Effect of fermentation on the sugar levels in co-fermented maize-cowpea blends.....	80
Fig. 19	Effect of fermentation on the sugar levels in co-fermented maize-cowpea blends.....	81
Fig. 20	Effect of fermentation on glucose concentration in co-fermented maize-cowpea blends.....	82
Fig. 21	Effect of fermentation on the sugar levels in fermented maize-cowpea blends.....	84
Fig. 22	Effect of fermentation on the sugar levels in fermented maize-cowpea blends.....	85
Fig. 23	Effect of fermentation on glucose concentration on fermented maize-cowpea blends.....	86
Fig. 24	Models to predict Brabender viscosity from Brookfield viscosity at 10rpm, temperature and concentration of maize slurries.....	91
Fig. 25	Models to predict Brabender viscosity from Brookfield viscosity at 10rpm, temperature and concentration of maize slurries.....	92
Fig. 26	Models to predict Brabender viscosity from Brookfield viscosity at 20rpm, temperature and concentration of maize slurries.....	94
Fig. 27	Models to predict Brabender viscosity from Brookfield viscosity at 20rpm, temperature and concentration of maize slurries.....	95
Fig. 28	Models to predict Brabender viscosity from Brookfield viscosity at 50rpm, temperature and concentration of maize slurries.....	97
Fig. 29	Models to predict Brabender viscosity from Brookfield viscosity at 50rpm, temperature and concentration of maize slurries.....	98

LIST OF TABLES

	PAGE
Table 1	Proposed model composition for supplementary foods..... 7
Table 2	Chemical composition of whole seeds of four local cowpea varieties..... 14
Table 3	Occupation of respondents..... 36
Table 4	Age of youngest child..... 39
Table 5	Incorporation of cowpea into food..... 41
Table 6	Reasons for feeding fermented maize dough porridge to their children..... 53
Table 7	Motivating factors that control the purchase of proprietary weaning foods..... 54
Table 8	Significant F-values for results of ANOVA..... 58
Table 9	Effects of millet malt on cooked paste viscosity of maize dough at 50°C and 50°C-HOLD.... 64
Table 10	Effect of maize malt on cooked paste viscosity of maize dough at 50°C and 50°C-HOLD.... 64
Table 11	Effect of sorghum malt on cooked paste viscosity of maize dough at 50°C and 50°C-HOLD.... 64
Table 12	Chemical composition of cowpea and maize..... 72
Table 13	Levels of mono-, di- and oligosaccharides as determined in cowpea..... 78
Table 14	Levels of mono- and disaccharides as determined in maize..... 78
Table 15	Table of significant F-values for ANOVA..... 87
Table 16	ANOVA summary table for water absorption capacity of cowpea-maize blends..... 88

1.0

INTRODUCTION

1.1 The weaning period - a crucial period in the life of an infant

Infants in developing countries generally show satisfactory growth during the first 6 months of life when they are almost exclusively breastfed (Cameron and Hofvander, 1971). Thereafter, there is the need to introduce supplementary foods in order to meet the infants increased nutritional requirements for protein, energy and other nutrients. Weaning foods are offered to the child with the dual purpose of supplementing nutrient intake and gradually weaning the infant off breastmilk (Cameron and Hofvander, 1971)

Cameron and Hofvander (1971) observed that "One of the greatest dangers of weaning period can be the results of the change over from sterile breast milk and its anti-infective factors to animal milk and semi-solid and solid foods, often acquired, stored and fed in unhygienic and unsanitary fashion. In fact, the weaning process is associated with the highest rate of infection, particularly of the gastrointestinal tract, that the child will encounter in its entire lifetime".

The resultant "weaning diarrhoea" may easily precipitate Protein Energy Malnutrition (PEM) leading to death if not handled properly. Nutrition is closely linked with health as it

influences infection. Each year, about 13 million infants die in the developing countries. Though the immediate cause of a majority of these deaths is parasitic and infectious diseases, most of the children die due to malnutrition (ACC/SCN, 1988).

Many approaches are needed to improve child survival and growth in developing countries. Among these are improved sanitation, breastfeeding promotion, immunizations, diarrhoeal disease control and the provision of safe and nutritious weaning foods (Jansen, 1992)

1.2 The shortcomings of traditional weaning diets

The diet of most people in developing countries is based on processed cereal grains such as maize, sorghum, and rice or roots and tubers such as yam and cassava (Bressani, 1985). These foods, because they are eaten in large quantities, provide the bulk of protein, but the quality of this protein leaves much to be desired.

Traditional weaning porridges are usually made from these local staples and the result is gruels that have low nutritional value as they are not adequate sources of micro- and macronutrients (Brown, 1991). During cooking the starch in these staples bind water, requiring considerable amounts of water to bring the consistency of the porridge to a level suitable for child feeding. This lowers the energy and nutrient density of the porridge considerably. This high volume/high

viscosity characteristic, referred to as dietary bulk makes it difficult for infants fed on these gruels to satisfy their nutrient requirements. This is considered as a major problem of malnutrition in areas where cereals and starchy staples are the main food (Ljungqvist et al., 1981).

The use of adult diet as weaning food is also a common practice but this is desirable if the nutrient density is adequate and the food is made easily digestible. Other practices such as food taboos and intrafamilial food distributions may also work to the detriment of the infant who is not yet able to fend for his/herself.

1.3 Weaning food formulation

Work has been done towards the development of some high-protein weaning foods from local staples (Eyeson and Plahar, 1988, Akpapunam and Sefa-Dedeh, 1994). The approach that has been commonly adopted has been the fortification of cereals with locally available legumes e.g. soya beans, cowpeas, etc.

Food grain legumes, because of their high protein content, in general constitute the natural protein supplement to staple diets. Protein quality is synergistically improved in cereal-legume mixes because of the lysine contributed by the cowpea and methionine contributed by the cereal (Bressani and Elias, 1980).

The use of processing methods such as extrusion, puffing, toasting, malting, steam treatment, dry roasting and fermentation have also been researched in attempt to reduce dietary bulk, antinutritional factors, undesirable flavours associated with legume utilization and inhibit bacteria pathogens. Although some of these technologies may be effective in producing optimum weaning diets they may be too technical or unacceptable to the rural population. Mensah and Sefa-Dedeh (1991), stressed the need to employ simple and inexpensive local technologies which can be adapted at home level to ensure wider acceptance among the population.

This study was aimed at investigating the effectiveness of traditional processing technologies; germination, fermentation and steaming in the development of a high-protein multimix of desirable functional and physico-chemical quality.

1.4 Main Objectives:

1. To obtain the views and perceptions on the quality attributes expected and the factors considered in the selection of a weaning food by mothers.
2. To investigate the effect of adding sorghum, millet and maize malts on the viscosity of cooked cereal-based porridges.

3. To determine the effects of traditional processes such as steaming and fermentation on the concentration of mono-, di- and oligosaccharides in cowpea/maize blends by the use of High Pressure Liquid Chromatography (HPLC).
4. To investigate the effect of cowpea fortification on the proximate composition, physico-chemical and functional properties of fermented maize dough.
5. To assess the use of the Brookfield viscometer, a simple tool for measuring the viscosity of cooked gruels and to compare it to the Brabender viscoamylograph.

2.0

LITERATURE REVIEW

2.1 The characteristics of a weaning food

The term "weaning food" usually describes solid or semi-solid food designed to be fed to an infant either partially or fully weaned from the breast (Jansen, 1992). In general, weaning foods should be soft so that they are easy for babies to chew, swallow and digest. They should not be irritating to the baby's digestive tracts and should be free of contamination (Mitzner et al., 1984).

In many traditional societies, the weaning child seldom receives specially formulated weaning foods. The child is instead gradually introduced to adult foods, starting with softer carbohydrate rich varieties (Mitzner et al., 1984). Often such foods do not contain all the nutrients that the child needs, or they are so dilute that the infant, whose stomach is small, cannot consume enough to supply the nutrients necessary for growth and development. In attempt to address this issue, food mixtures, specially formulated for the weaning child have been developed.

Weaning foods, when combined with other foods that are being consumed, need to ensure that the nutritional needs of the infant or young child are met according to national and international standards. Establishing a definite nutritional standard for weaning foods is difficult because of the great

variety of conditions under which they are used. The needs of a child may vary considerably depending on age, breastmilk consumption, consumption and nature of the home diet, amount of supplement consumed and other factors.

The product course of action is to develop a supplementary food with nutrient levels such that when combined with low income, heavily cereal-based diet, the nutrient requirement of the targeted child are met. The Codex Alimentarius Commission has proposed a model composition for supplementary foods designed to be fed to infants 4-6 months onwards and to infants (FAO/WHO, 1985). (Table 1)

Table 1 Proposed Model Composition for Supplementary Foods^a

	Amount		
	Per 100g	Per 100Kcal	Per100kJ
Protein ^b (g)	20	5.2	1.2
Fat (g)	10	2.6	0.6
Crude fibre (g)	5	1.3	0.3
Vitamin A as retinol (μ g)	400	100	24
Vitamin D cholecalciferol (μ g)	10	2.5	0.6
Vitamin E (alpha-tocopherol) (mg)	5	1.25	0.3
Ascorbic acid (mg)	20	5.2	0.12
Thiamin (mg)	0.5	0.12	0.03
Riboflavin (mg)	0.8	0.20	0.05
Niacin (mg)	9	2.2	0.57
Vitamin B ₆ (mg)	0.9	0.22	0.06
Folic acid (μ g)	100	27	6
Vitamin B ₁₂ (μ g)	2	0.52	0.12
Calcium (mg)	800	200	48
Phosphorus (mg)	800	200	48
Iron (mg)	10	2.7	0.6
Iodine (ng)	70	18	4.5

^a Data from Joint FAO/WHO Food Standards program. Codex Alimentarius Commission.

^b Protein should have score of 65 and a PER of 2.2 (casein=2.5).

2.2 The requirements of a weaning food

The quality of the weaning diet as well as the quantity should be of primary concern in the formulation or improvement of weaning foods.

Whereas the concept of dietary quantity usually refers to the total amount of food energy which can be measured, dietary quality remains rather vaguely defined and difficult to measure (Brown, 1991). Among specific characteristics of a weaning diet that may contribute in quality determination are:

- energy density
- macro and micronutrient density
- digestibility and bioavailability
- diversity of diet
- absence of antinutritional factors
- appropriate organoleptic characteristics for age

Most attention has been directed towards the fulfilment of protein and energy requirement because of the widespread occurrence of protein energy malnutrition (PEM) and linear growth retardation in developing countries. But the heavy dependence on cereals and root crops among the poorer segments in developing countries has resulted in the prevalence of other nutrient deficiencies e.g. vitamin A, iodine and zinc.

Macro-and micronutrients are both essential to optimum

growth and development of the weaning infant therefore the diet must adequately meet the child's requirements.

2.3 The development of weaning foods

In developing countries, weaning foods can be divided into two categories (Jansen, 1992):

1. common household foods (e.g. corn, cassava, rice, yam,
2. mixtures specially formulated for infants nutritional needs.

Techniques commonly employed in weaning food development include the formulation of high-quality protein foods and the enrichment of traditional foods by the incorporation local staples. The high-quality protein mixes are developed using local staples and/or imported ingredients and are usually processed on industrial scale. The use of sophisticated technology e.g. extrusion, drum drying may elevate the cost of production and hence the end product cost.

The rationale behind the supplementation of a staple food is that the nutritional quality of a commonly used food may be enhanced by the addition of small amounts of other foods that are rich sources of nutrients limiting the nutritional utilization of the staple food. This alternative may be less expensive than producing a new food and may be more easily

adopted (Jansen, 1992). Local food processing methods can be made use of in the processing of these foods. These technologies appear to be very attractive since they are traditional and so would be expected to be not only feasible, but perhaps more culturally acceptable and more effectively promoted than a new behaviour pattern (Ashworth and Draper, 1992).

Weaning foods must thus be cheap, culturally acceptable, made of locally available foods and easily and quickly cooked.

2.4 Traditional food technologies and infant feeding

Food processing technologies, traditional and sophisticated facilitate the utilization of food by converting the raw materials into diverse end products with desirable characteristics.

In most developing countries, weaning foods are based on local staples, usually cereals. These cereals are normally made into gruels by the help of processing methods developed through the years based on traditional home practices. Common food technologies used in the preparation of these gruels include germination and fermentation and legume fortification. Unit operations such as dehulling, size reduction, soaking and drying play an important role in the development of product quality.

2.4.1 Germination

Malting is a traditional practice in developing countries primarily used in the production of alcoholic drinks and non-alcoholic beverages. During germination of the grains, α -amylase and β -amylase activity is developed. These enzymes effectively degrade starch granules reducing their water binding capacity. Germination among the low-cost methods available to reduce the high viscosity of cereal-based gruels seems to be the most effective (Desikachar, 1980). Although the viscosity effect is recognised in some communities in India and Africa, germination is not widely used in making weaning foods, perhaps because the preparation of germinated flour is rather time-consuming (Mosha and Svanberg, 1983). The incorporation of a small amount of germinated grain, amylase rich flour (ARF) to a cereal gruel has been reported to produce a remarkable reduction in viscosity (Hansen, 1989; Marero et al, 1988). Germination does carry certain advantages from the point of view of safety by the removal of toxic and anti-nutritional substances such as the removal of lectin and haemagglutinins (Nnanna and Phillips, 1988). But there is also the danger of contamination in the case of porridge to which ARF is added to porridge after cooking. This method has some constraints with respect to handling and proper application particularly by illiterate mothers (Ashworth and Draper, 1992; Gopalas et al 1982).

Roasting the malted grain is one of the options that have been investigated (Gopalas et al, 1988) but this makes the processing more involving and energy requiring.

Akrapunam and Sefa-Dedeh (1994), incorporated ARF into the maize dough prior to fermentation. This was done with the intention of utilizing the antimicrobial effect of fermented maize dough to inhibit pathogenic bacteria concurrently with the viscosity reduction potential of the ARF. They reported that increases in viscosity due to fermentation overshadowed the viscosity reduction potential of ARF. It may be desirable to add the malt flour to the dough after fermentation.

Germination is also reported to increase free amino acids and sugars in cereals (Parameswasan and Sadasivam, 1992).

2.4.2 Fermentation

Solid state fermentation of cereals is widely applied in the processing of cereals for the preparation of a wide variety of dishes (Obiri-Danso, 1994). In Ghana, the traditionally recommended weaning porridge is prepared from fermented maize dough. The soaking of the grains in excess water allows the selection of desirable microorganisms, such as lactic acid bacteria, yeasts and moulds (Akinrele and Bassir, 1967). The activity of these microorganisms reduces pH and increases the titratable acidity of the substrate. A number of fatty acids are also produced (Akinrele, 1970; Muller, 1970; Plahar and

Leung, 1982).

The sour taste developed as a result of the acids produced is a desirable sensory attribute. This tangy taste has been reported to appeal to infants especially those who are ailing and unable to feed properly (Phillips and Abbey, 1989). In

In 1990, Mensah et al studying the properties of fermented maize dough observed significant inhibition of pathogenic bacteria. Cooking the dough into porridge reduced the antimicrobial effect but there was still significant inhibition of pathogen. This antimicrobial property could be an important strategy for the reduction of the high levels of faecal bacteria in weaning foods in developing countries.

The increase of niacin and riboflavin contents (Cameron and Hofvander, 1971) and the release of phosphorus from phytate (Lopez et al, 1983) are among the several benefits derived from the fermentation of maize. The lactic fermentation of cowpeas by the lactic acid bacteria (*Lactobacillus plantarum*, *Lactobacillus fermenti*) has been reported to eliminate flatulence causing oligosaccharides (Duszkiewicz-Reinhard et al, 1994). Legume has also been reported to improve protein digestibility (Barampama and Simard, 1994)

2.5 The choice of cowpeas as a fortification agent

Food grain legumes represent the main protein source consumed by a majority of the population in developing countries (Bressani, 1993). Cowpea (*Vigna unguiculata*) is a popular legume that is widely used in West Africa and it serves as an economic source of proteins and calories (Nnanna and Phillips, 1990) (Table 2). Cowpea also provides thiamine and riboflavin to the diet. In addition to its nutritional impact, legume protein reduces plasma low density lipoprotein when consumed.

Table 2 Chemical composition of whole seeds of four local cowpea varieties

Nutrient	VARIETIES			
	Asontem	Ayivi	Bengpla	Soronko
Moisture *	14.16	14.29	14.62	15.20
Protein (%) ^d	24.11	26.74	24.62	25.47
Fat (%)	1.61	2.10	1.79	2.00
Crude Fat (%)	4.64	3.97	4.11	3.81
NFE ^e	51.43	48.98	51.11	50.20
Ash (%)	4.14	3.92	3.75	3.32
Minerals (mg/100g)				
Na	1.51	1.65	1.57	1.27
Ca	2.32	2.24	2.26	2.15
Fe	11.50	9.10	12.02	9.19

* All values were reported on dry matter basis.

^d N x 6.25

^e Nitrogen Free Extract calculated by difference.

Source : Osei, (1994)

Though cowpea is cultivated worldwide, in 1981 it was reported that two thirds of the total crop worldwide, was harvested on the African continent (Bressani and Elias, 1980).

However, the utilization of cowpea as food is below its potential. The underutilization of legumes has been attributed to factors such as the prolonged cooking times required to prepare legume-based foods, methionine deficiency in legume protein, presence of heat stable and heat labile factors that interfere with digestion and gastro-intestinal distress and flatulence associated with legume consumption (Phillips, 1993). The nutritional quality of starchy legumes is further limited by the inherent resistance of major globulins to digestion.

To utilize cowpeas as a more acceptable source of inexpensive protein, it is desirable to reduce the level of antinutritional factors and develop food applications. The use of some traditional technologies such as germination (Nnanna and Phillips, 1990), soaking and cooking (Abdel-Gawad, 1992), lactic acid fermentation (Reddy and Salunkhe, 1980, Mital and SteinKraus, 1974) (Duszkiewicz-Reinhard, 1994) and dehulling (Akinyele and Akinlosotu, 1982) have been used to effectively reduce the levels of antinutritional factors in legumes. Steaming and roasting are known to reduce the undesirable beany flavour and also eliminate the effects of heat-labile antinutrients in cowpea.

2.6 Functional and chemical properties of weaning foods

Specific functional characteristics are required for every food system (Pour-El, 1981). Functional property of a food is

important because it indicates the utility of products in specific applications and therefore reflect the properties encountered by their use during the preparation of usable products (Sefa-Dedeh, 1993).

The functionality of food depends on its chemical composition and properties. This is because food is made up of aggregates of biological molecules including fats, carbohydrates and proteins which react constantly depending on their environments. It is this reaction and interaction between food constituents and determines the functionality of that particular food system.

The ultimate application of cereals and legumes is the conversion into edible forms for human consumption. The application of processing technology e.g. temperature, enzymes, size reduction, hydration in weaning food production affects the chemical properties and therefore the functionality of the food.

Viscosity and water absorption characteristics are important functional properties of cereal-based porridges. Starch, a major carbohydrate in cereals and legumes, has the ability to absorb water suspension of the granules is heated above gelatinization temperature (Rasper, 1982). The swelling of the granules and their consequent disintegration on prolonged heating leads to significant changes in viscosity and other rheological properties of the paste that are characteristic of the particular type of starch.

Since the effects of mixing different components is not simply additive; evaluation of the individual components is at best only a partial predictive tool (Scheon, 1977). Therefore, in product formulation, the determination of functional properties of the components of the mixture and the end product are clearly of prime importance and must be measured.

2.6.1 The functionality of cowpea-fortified preparations

The important role grain legumes play in the diets of many populations in protein-deficient countries has prompted research on various aspects of legume utilization (Sefa-Dedeh and Yiadom-Farkye, 1988).

One such area is that of raw material/product functionality desirable for efficient processing and consumer acceptability. Much research has been published on cowpeas which can promote the development of processes and products for the consuming public (Sefa-Dedeh, and Demuyarko, 1994; Akinyele and Akinlosotu, 1991; Phillips et al., 1988; Abbey and Ibeh, 1988).

The chemical composition of cowpea, like most edible legumes contains 20-30%, about 62% soluble carbohydrates and small amounts of other nutrients (Bressani, 1985; Phillips, 1993). Because the protein content of legumes is higher than in most vegetables, the other major component; carbohydrates is often neglected.

The amylase in the starch of cowpeas, influences starch solubility and many functional properties such as swelling water absorption and pasting (Bressani, 1985). The protein in cowpea also gives rise to some functional characteristics including foaming, shipping and binding properties which are desirable sensory quality characteristics especially in fried foods.

Functionality studies of cowpeas on model systems provide insights into the compatibility of cowpea as a food ingredient, and therefore the success with which cowpeas can be incorporated into various foods (McWatters, 1985). This is important as the nutritional benefits of food fortification cannot be at the expense of sensory and functional quality of a product is to be acceptable to consumers (Bressani, 1985).

The cowpea-fortification of cereal products markedly improves the protein content of the mixture and this influences the rheological properties of the blend. Cowpea-Fortification to cereal porridges has been reported to increase the total nutrient density by more than two-fold as a result of a reduction in viscosity (Marero et al., 1980; Malleshi et al., 1989). Malleshi et al., 1980 described this decrease in viscosity to be comparable to the dextrogenic effect of α - and β -amylases in germinated cereal.

Sefa-Dedeh and Osei (1994) reported a marked increase in water absorption of steamed and unsteamed cowpea fortified maize

dough. The change in functionality accompanying the cowpea fortification of cereal-based porridges is desirable.

2.7 The benefits of consumer input in product development

Consumer input in the product development is important especially when a product is targeted at a specific market. Acceptability of a product is a necessary quality index, as it motivates a potential customer to purchase the product. Product acceptability may encompass other quality criterion such as taste, flavour, colour and functionality of the product.

Consumer data is useful at different stages of the development cycle:

- (a) product concept development
- (b) product optimization
- (c) end product evaluation

At the conception state it is crucial to obtain data on the potential uses of the product, market available, perceptions and preferences expected in a product. This information may be the basis of a number of decisions to be taken. Consumer information is best obtained through interaction with potential customers.

Product optimization and product evaluation measures may involve some amount of quality assessment. Because of the complexity of physical, chemical and sensory properties of many

foods, qualitative as well as instrumental measurements are needed to obtain optimum information.

The total impression of aroma, flavour, taste, texture and colour for example that are acceptable or preferred in a particular product are best determined through the application of sensory analysis arranged for potential consumers. Consumer input information obtained during product development can save a producer the cost of altering a finished product to suit the consumer (Jellinek, 1985).

Qualitative research is a valuable tool used to collect consumer data in the product development cycle.

3.0**MATERIALS AND METHODS****3.1 Materials**

Sorghum (*Sorghum bicolor*), millet (*Eleusine coracana*), maize (*Zea mays*) and cowpeas (*Vigna unguiculata*) were used in the experiments. An improved variety of maize (*Abelehii*) was purchased from Ejura Farms for the experimental work carried out. Dent corn and Blackeye peas obtained from the Centre for Food Safety and Quality Enhancement (CFSQE), was used for the experimental work performed at the University of Georgia, U.S.A. All the grains and samples were stored at a cold room temperature of 4°C during the experimental period.

3.2 Methodology**3.2.1 Field survey - questionnaire administration**

Background data and information on the expectations of the cost and quality attributes that are desirable in a weaning food was obtained by the means of a questionnaire (Appendix). Consumer oriented sensory evaluation was also conducted on four (4) manufactured and two (2) traditional weaning foods. Mothers were asked to rank the samples based on their preference for, or degree of liking with respect to colour, texture and consistency. The questionnaire was administered to mothers selected at random from four (4) locations in Accra where they

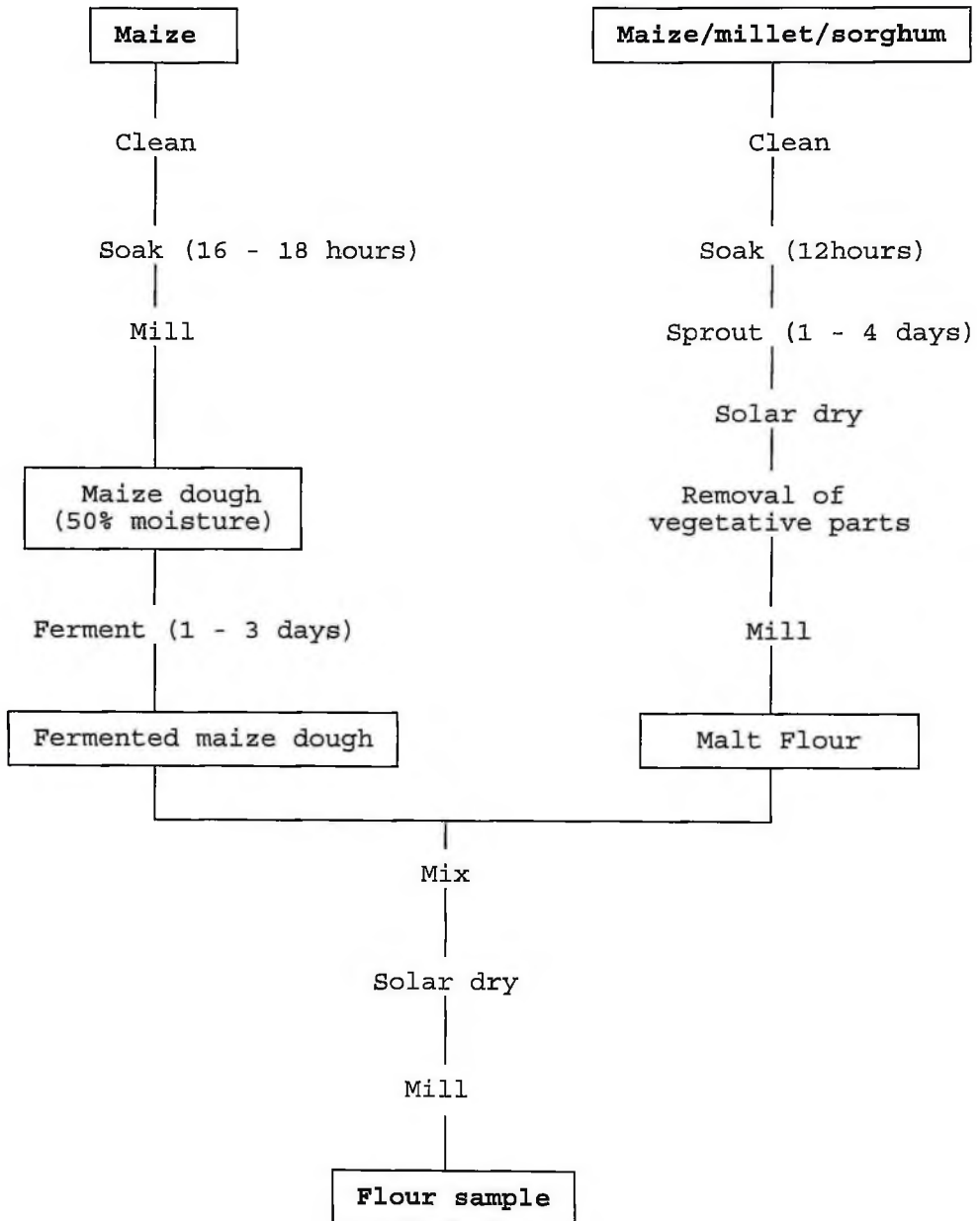
attend Child Welfare Clinic. The four locations were: The Princess Marie Louise Hospital, Adabraka and Labadi polytechnics and the Public Health Services Unit of the Kaneshie Polytechnic for the neighbourhood.

3.2.2 Laboratory studies

3.2.2.1 To investigate the effect of the addition of cereal malt (sorghum, millet and maize) on the viscosity of cooked cereal based porridges.

Maize, millet and sorghum were soaked separately in water for 18 hours at room temperature (Fig. 1). The steep water was drained and the grain allowed to germinate in sterilized woven baskets lined with sterilized jute sacks. The grains were watered lightly twice each day to ensure that the jute sacking was always moist as this would facilitate optimum seed germination. The grains were allowed to germinate for 24, 48, 72 and 96 hours dried in a solar dryer (for an average of 8 hours a day for 5 days) to a moisture content of 7.9- 8.8%. The dried grains were rubbed between the palms to remove the vegetative parts from the seed, the former was discarded. The seeds were milled into fine flour to pass through a 1mm sieve using a Hammer Mill (Christy and Morris Ltd, Chelmsford, England).

Fig. 1 Fermented maize dough fortified with cereal malt.



Whole maize grains were soaked in water (1:3,w/v) at room temperature for 16-18 hours. The steep water was drained and the grain milled using a disc attrition mill (Agro Grinding Mill, No.2A, India). The resulting meal was kneaded into a dough after bringing the moisture content to 50% by adding water. The dough was then allowed to ferment at room temperature for a period of 1-3 days in a container. Weighed quantities of cereal malt flours were added to the fermented maize dough and the mixture kneaded thoroughly and solar dried. The solar dried meal was milled into flour in a Hammer mill.

Experimental Design

A (3 x 3 x 2) factorial experimental design was used. Principal factors investigated in the experimental design were:

- i. sprouting time allowed for cereals : 2, 3, 4 days;
- ii. cereal malt concentration in dough : 5%, 10%;
- iii. type of cereal sprouted : maize, millet, sorghum.

Cooked paste characteristics of 8% slurries of the doughs were analyzed using the Brabender Viscoamylograph. The data was subjected to analysis of variance.

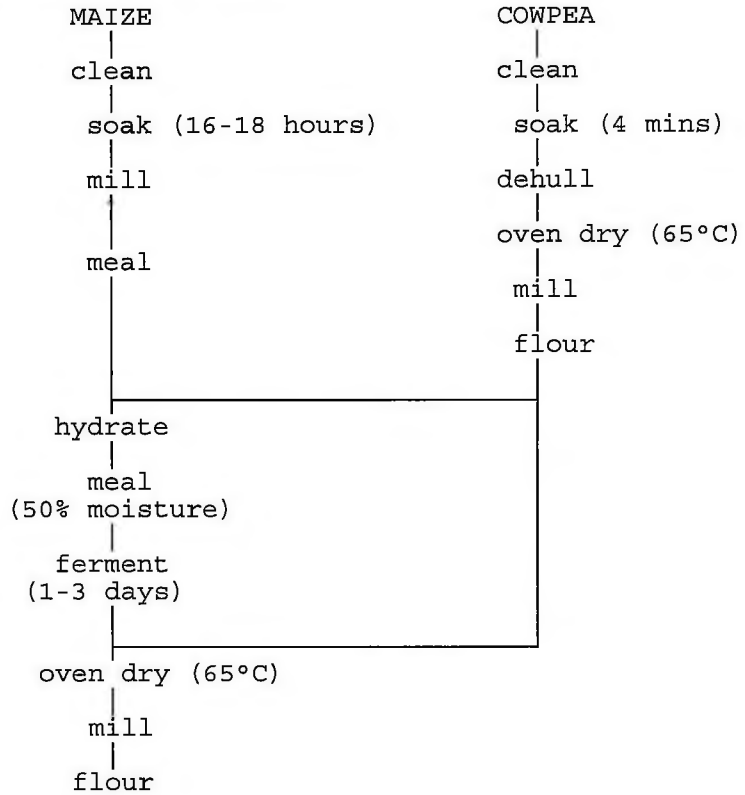
3.2.2.2 To investigate the effects of cowpea steaming and fermentation conditions on the proximate composition and the sugar concentration in maize-cowpea blends

Whole cowpeas were soaked in water for 4 minutes to loosen the seed coats (Sefa-Dedeh, 1994). The seeds were drained and dehulled using a disc attrition mill. The hulls were separated by flotation in water. One portion was dried in an oven temperature of 65°C for a period of 20-24 hours the remaining portion was steamed for 4 minutes. Subsequently the steamed seeds were oven dried at 65°C and milled into flour samples using a disc attrition mill. Whole maize grains were soaked in water (1:3,w/v) at 28°C for 18 hours. The steep water was drained and the grain milled using a disc attrition mill (Agro Grinding Mill, No.2A, India). Figures 2A & B are the flow diagrams for the processes.

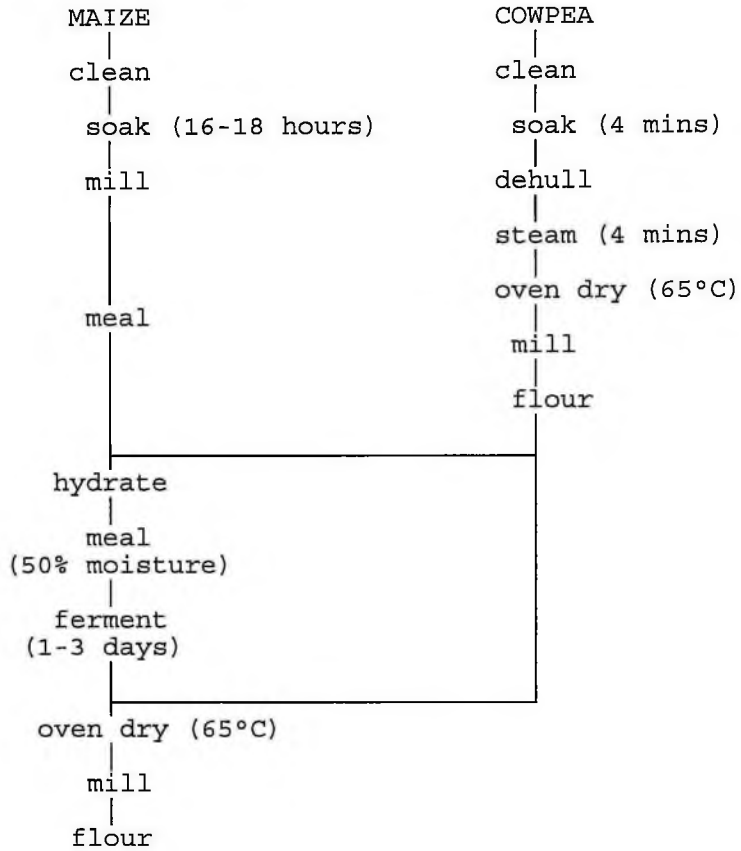
Several formulations were prepared by the addition of weighed portions of dehulled and steamed cowpea flour to maize meal before fermentation. The resulting meal was kneaded into a 50% moisture dough, allowed to ferment at room temperature for a period of 1-3 days. Other blends were formulated by the addition of cowpea flours to the maize dough after fermentation. The preparations were dried in a oven at 65°C and milled into flour.

Fig. 2 Maize-cowpea blends prepared for analyses.

(a) Unsteamed Cowpea



(b) Steamed Cowpea



Design of Experiment

A 5x4x2x2 factorial experimental design was used. The variables under study were ;

- a) cowpea level (0, 5, 10, 15 and 20%)
- b) fermentation time (0, 1, 2 and 3 days)
- c) steam treatment
- d) fermentation method

Samples were evaluated for moisture, water absorption, protein, fat, ash and mono-, di- and oligosaccharides. Also evaluated was pH and acidity of the dough prior to dehydration.

3.2.2.3 Assessment of the Brookfield viscometer, a simple tool for measuring the viscosity of cooked gruels and to compare it to the Brabender viscoamylograph.

Whole maize grains are soaked in water (1:3,w/v) at 28°C for 24 hours and fermented for 48 hours (see 3.2.2.2)

Design of experiment

Viscosities of 6%, 8% and 10% (dry matter basis) slurries of the fermented and non-fermented flours prepared were determined on the Brookfield viscometer and Brabender viscoamylograph. The data was correlated and subjected to multiple regression analysis.

3.2.3 Chemical analyses

3.2.3.1 Determination of mono-, di- and oligosaccharides

Sugars were extracted from maize/ cowpea blends using a mixture of chloroform: methanol (1:1,v/v) and water as in Havel et al,1977. Extract was concentrated under vacuum, made to 5ml with de-ionized distilled water. The extract was filtered with 0.22m PTFE filters and stored in 5ml ampoules at a cold room temperature of 0°C. 10 μ L samples were analyzed by High Performance Liquid Chromatography (HPLC) using a Hitachi system equipped with a Hewlett Packard integrator and Shimadzu refractive index detector. Separation was done on a 220 x 4.6mm amino propyl column (amino-spheri-5, Brownlee Labs, Santa Clara) eluted with a 70:30 v/v mixture of acetonitrile: water which contained 0.01% tetraethylene pentamine (TEPA) as recommended by Aitzemuller (1978). Quantification was against authentic external standards of the sugars detected and a lactose internal standard.

3.2.3.2 Proximate analyses

The crude protein (N x 6.25), fat, and ash contents were determined by AACC methods 46-12, 30-20 and 08-03 respectively (AACC,1983).

3.2.3.3 Physico-chemical properties

3.2.3.3.1 pH and Acidity

AACC (1983) method No. 02-31 was used with modification. Ten grams of the fresh dough samples was mixed with 100 mL of distilled water and allowed to stand for 30 minutes with intermittent mixing. The supernatant was collected and its pH measured. Ten mL aliquot of the filtrate was made up to 100 mL with distilled water and titrated against 0.1N NaOH to phenolphthalein end point. Titratable acidity was expressed as gram lactic acid per 100 g of dry sample. All determinations were performed in duplicate.

AOAC (1975) method No. 14.022 was used to determine the pH.

3.2.3.4 Functional Properties

3.2.3.4.1 Water Absorption

The method of Sosulski (1962) was used with modification. Five grams of flour was mixed with 30g of water and allowed to stand for a period of 30 minutes. The suspension was centrifuged at 3000rpm for 20 minutes. The amount of water absorbed was measured as the increase in weight of the flour sample after all the supernatant had carefully been decanted. Results were reported on dry matter basis.

3.2.3.4.2 Cooked Paste Viscosity

(a) Brabender Viscoamylograph Characteristics

AACC method No. 22-10 (1983) was used with modifications. The cooked paste viscosity and pasting characteristics of an 8% slurry (dry matter basis), of flour samples was determined by the use of the Brabender Viscoamylograph (Viskograph PT 100, Brabender Instrument Inc. Duisburg, West Germany) equipped with a 700cmg sensitivity cartridge. The weighed sample was mixed with water and made up to 500mL in a volumetric flask. The suspension was heated at the rate of 1.5°C / minute to 95°C, held at this temperature for 30 minutes, cooled at 1.5°C /minute at 50°C and held at this temperature for 30 minutes. The slurry was agitated at 75 rpm (bowl speed).

(b) Brookfield Viscosity Measurements

Viscosity measurements were made on 500ml portions of 6%, 8% and 10% (dry matter basis) slurries of flour samples by the use of the Brookfield viscometer (Model RVTB+). Each slurry was heated to 95°C, held at constant temperature for 30 minutes and then cooled to 50°C. Viscosity was measured at 95°C (initially and after holding for 30 minutes), 80°C, 70°C, 60°C and 50°C. Measurements were taken at four spindle speeds 10, 20, 30 and 50 rpm.

Viscosity profile indices : Pasting temperature, peak viscosity, viscosity at 95°C, viscosity after 30 minutes at 95°C, viscosity at 50°C, viscosity after 30 minutes at 50°C and maximum setback viscosity were measured from viscosity measurements taken on both viscometers.

3.2.4 Data Analysis

All the statistical analysis and graphical presentations were done using Statgraphics (Graphic Software System, STCC, Inc. USA) and Freelance softwares.

4.0

RESULTS AND DISCUSSION

4.1 Mothers' perceptions of quality attributes in a cowpea based infant weaning food

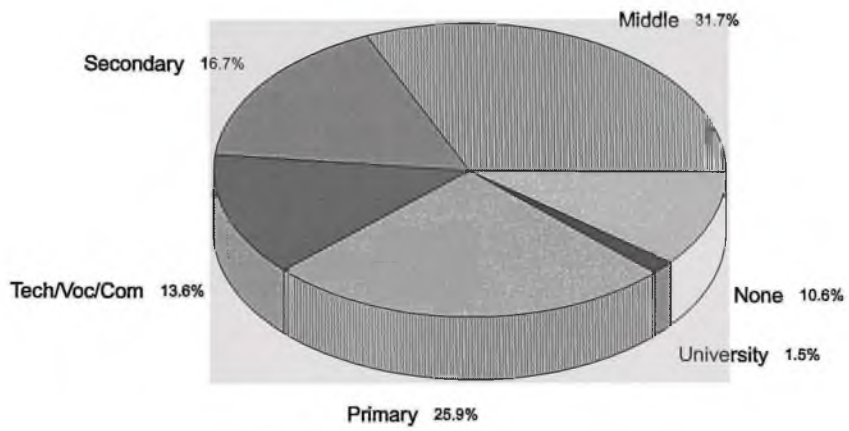
4.1.1 Background data on respondents

The environment plays a great role in a child's growth and health. Micro-environmental conditions such as living conditions and sanitation have been implicated in the synergism of malnutrition and infection (Tomkins and Watson,1989). The influence of the macro-environment, including social, economic and cultural variables on child rearing practices is also well established. In addition, various maternal attributes have also been shown to be important in the aetiology of malnutrition (Subbulakslimi and Udipi,1990). Education is a key variable which in addition to women's decision making power, has been shown to influence their knowledge about food and health although the relationship to nutrition is not completely clear (Holmboe-Ottensen,1989).

A total of a hundred and thirty-two (132) mothers were interviewed. On the average, the respondents had a wide range of educational experience and also were from different walks of life. A tenth of the mothers had had no formal education (10.61%) whilst 63.64% had at least secondary level education (Fig.3). Those respondents who had technical, vocational or commercial training (13.64%) included secretaries, nurses,

Fig. 3 Educational background of the respondents

Tech/Voc/Com = Technical/ Vocational/Commercial



dressmakers and caterers. Literacy is an essential maternal attribute. This is because it enables the mother to respond to nutrition education and better understand the basic principles of infant nutrition. Nutrition education is essential for creating awareness of desirable weaning practices among mothers. It is important to note that most of the mothers interviewed were educated (ie. 89.4%); and were employed (82.6%). This means that a large number of the respondents were in the position to supplement the family income and respond to nutrition education. Mothers with a good understanding of proper child nutrition will be an important factor that could facilitate effective improvement of infant nutritional status.

The largest group of the respondents interviewed (45.5%) were classified as traders (Table 3). This number included food vendors, petty traders and wholesale traders. The unemployed respondents, the majority of which were housewives (91.3% of the unemployed were housewives), totalled 17.4% of the subject population whilst the percentage of mothers in government employment and private business were 13.6% and 22.7% respectively. Those in government employment included teachers, nurses, secretaries and receptionists. The self-employed or those employed by private organizations included hairdressers, seamstresses, caterers and teachers. The respondents represented a cross-section of different status and socio-economic class. The wide background of the sample is advantageous in that the information gathered will not only reflect the behaviour of views of one but rather a cross-section of socio-economic groups.

Table 3 Occupation of Respondents

Occupation	No. of mothers	Percentage of mothers
Traders	60	45.5
Privately employed	30	22.7
Unemployed	23	17.4
Government employed	18	13.6
Student	1	0.8
TOTAL	132	100

Some studies carried out, directly related the child's nutritional status to the income earned by the mother or father. A field study in Ghana revealed that even when both the father and the mother were employed, it was the income of the mother that made the most significant impact on the nutritional status of the children (Holmboe-Ottensen *et al*, 1989).

The primary responsibility for child care lies with women. There are many variables that affect women's role and child care activities. These include constraints such as availability of money or level of income, time and energy that largely depend on her employment status and the socio-economic level of the household.

Seventy percent (70.0%) of the responding population had less than three children (Fig. 4). Whilst more than a third of the mothers had more than two children. More than half the mothers had a child that was less than a year old at the time of the interview, and therefore were in the position to give accurate information on everyday infant feeding practices.

Nearly forty percent (39.4%) of these children were below six months of age (Table 4). The majority of mothers were young women (who had had only one or two children) and therefore would benefit from mother and child nutrition and health care education given at the public health centres. The illiterate mothers are bound to benefit too since the education is given in the local Ghanaian languages.

Fig. 4 Number of children born to each respondent

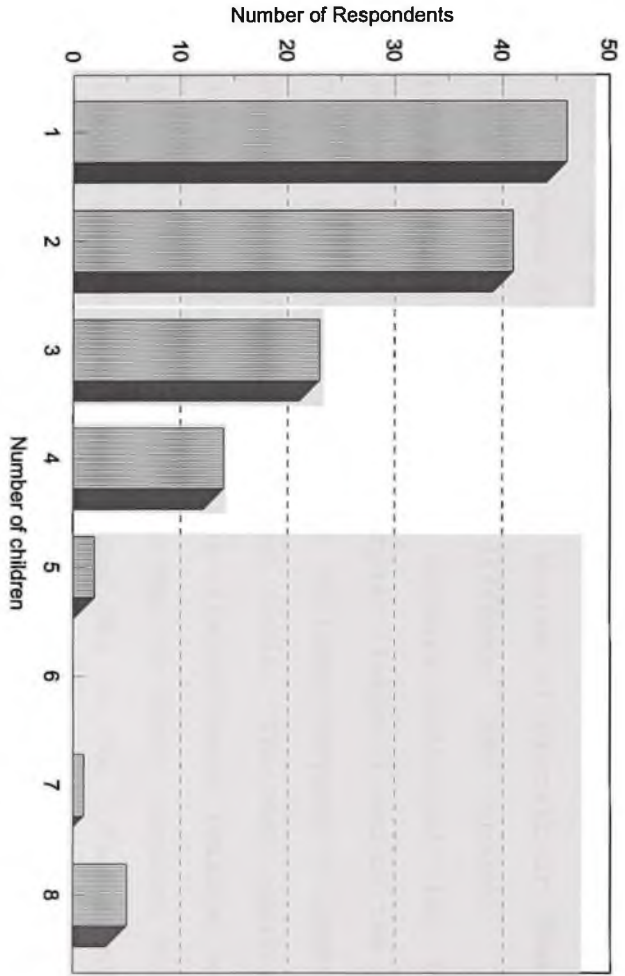


Table 4 Age of youngest child

Age of last child	Number of Respondents	Percentage of Respondents
Less than 1 month old	10	7.6
Less than 2 months old	15	11.4
Less than 3 months old	22	16.7
Less than 6 months old	52	39.4
Less than 12 months old	90	68.2
Less than 18 months old	98	74.2
Less than or equal to 24 months	107	81.1
Above 24 months of age	25	18.9

4.1.2 The use of cowpeas in infant food preparation

Cowpea is an important source of protein in Ghana. Its consumption spans across different age groups. In the population study, 17.4% of mothers indicated that they fed cowpea to their children everyday (Table 5) and on the average, 72% of the mothers fed their children cowpeas at least once a week in a variety of different foods. The most popular dishes into which cowpea was used was rice and beans (*Waakye*) and beans and gari (Fig. 5). *Apapransa* was the least popular dish among the respondents. Other dishes fed to the infants into which cowpea was incorporated included *banku*, porridge, stews and soups, *akasa* and *mpotompoto*.

Fig. 5 Foods prepared at home with the incorporation of cowpeas

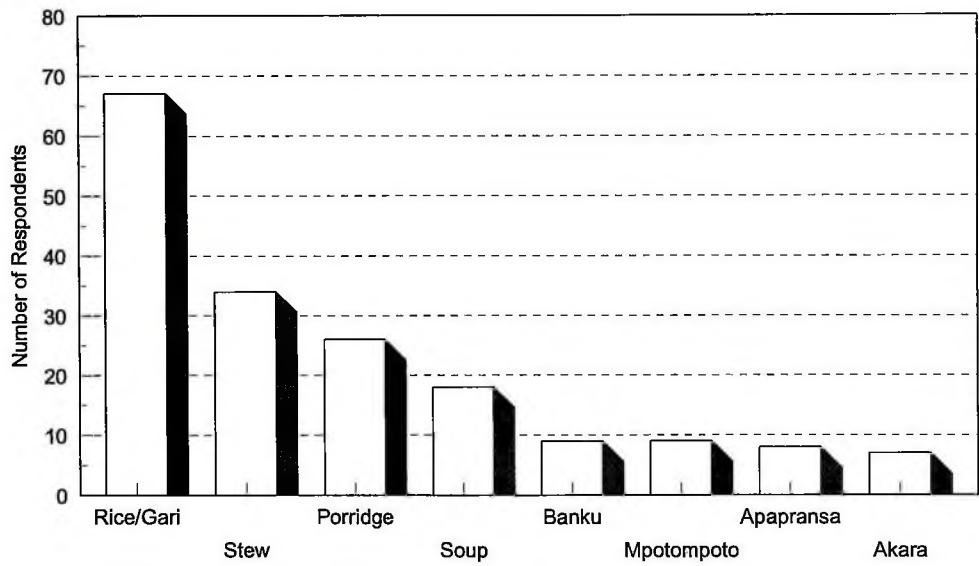


Table 5 Incorporation of cowpea into infant diets

Frequency per week	Number of mothers	Percentage of mothers
0	37	28.0
1	17	12.9
2	17	12.9
3	27	20.4
4	9	6.8
5	1	0.8
6	1	0.8
7	23	17.4
TOTAL	132	100

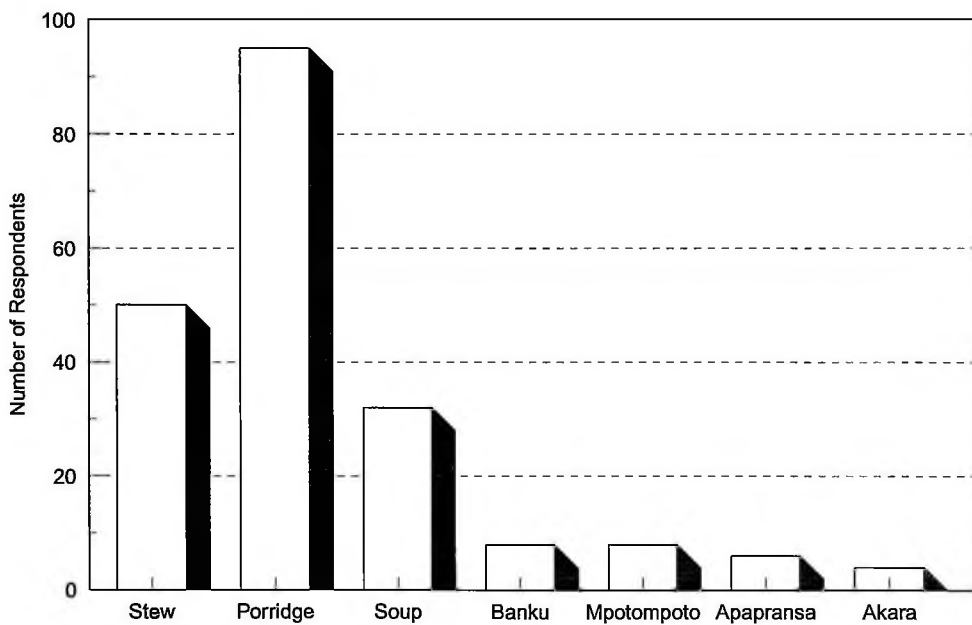
Mothers who did not feed cowpeas to their infants were thirty-seven in number (28%). One of the mothers who happened to be unemployed, indicated that cowpeas was too expensive whilst nine mothers believed that their infants were too young to be fed cowpeas in any form as they knew that cowpeas could cause gastric problems in young children. Nine of the mothers gave no reason for not offering cowpeas to their infants whilst four mothers said it was not safe for their infants since cowpeas was known to cause diarrhoea when fed to young children. Thirteen of the mothers said their infants rejected foods made with cowpeas. One mother preferred soybeans which had been recommended to her by a public health nurse.

The identification of diarrhoea, vomiting, abdominal pains and gas as side effects of cowpea consumption is in agreement with the reports of other workers (Hussain *et al*, 1992; Wagner *et al*, 1977).

One possible contributing factor of abdominal discomfort and other symptoms that has been proposed is the co-existence of parasitic infection. *Ascaris lumbricoides*, a common intestinal parasitic infection of adults and children in the third world countries, produces an anti-enzyme polypeptide ascarase that neutralizes trypsin and chymotrypsin (Hussain et al,1992) thereby inhibiting digestion. The diarrhoea occurring after eating cowpeas may be due to an increase in stool water content caused both by hypersmolar effects of the products of fermentation of the non-digestible alpha-galactosides in the colon and by the generation of water in the fermentation.

The majority of the mothers responded positively to the use of a processed form of cowpeas and proposed various foods to which this product could be added (Fig 6). The foods mothers proposed to incorporate cowpea flour into, were the same foods which they already prepared with cowpeas in the home (Figs. 5 & 6). Rice and beans, and Beans and gari were however not proposed for the obvious reason that the beans in these dishes remains whole after cooking and therefore using beans in a powdered form would be inappropriate. This also implies that cowpea flour could be used in the home without having to introduce new recipes. Majority of the mothers saw porridge as a potential food for the incorporation of cowpeas and this could increase the likelihood of the introduction of cowpeas into the diet of an infant in the home. A hundred and eighteen (89.4%) of the mothers said they would incorporate cowpeas into food

Fig. 6 Foods proposed to be suitable for the incorporation of
cowpea flour



given to their infants if it was in a powdered form. Only four of these mothers rejected the idea of a pre-cooked flour which could be incorporated into different foods eaten by infants in particular and the family as a whole. This resulted in a total of a hundred and twelve (84.8%) respondents who would welcome a pre-cooked and powdered form of cowpeas as a product on the market.

Pre-cooking cowpea is known to remove the undesirable beany flavour associated with cowpeas. Heat treatment can also reduce the levels of heat labile antinutrients such as enzyme inhibitors, oligosaccharides and improve the digestibility of protein in the legume. Therefore pre-cooking treatments such as steaming applied to cowpea prior to its processing into flour would facilitate the production of a product of improved nutritional value.

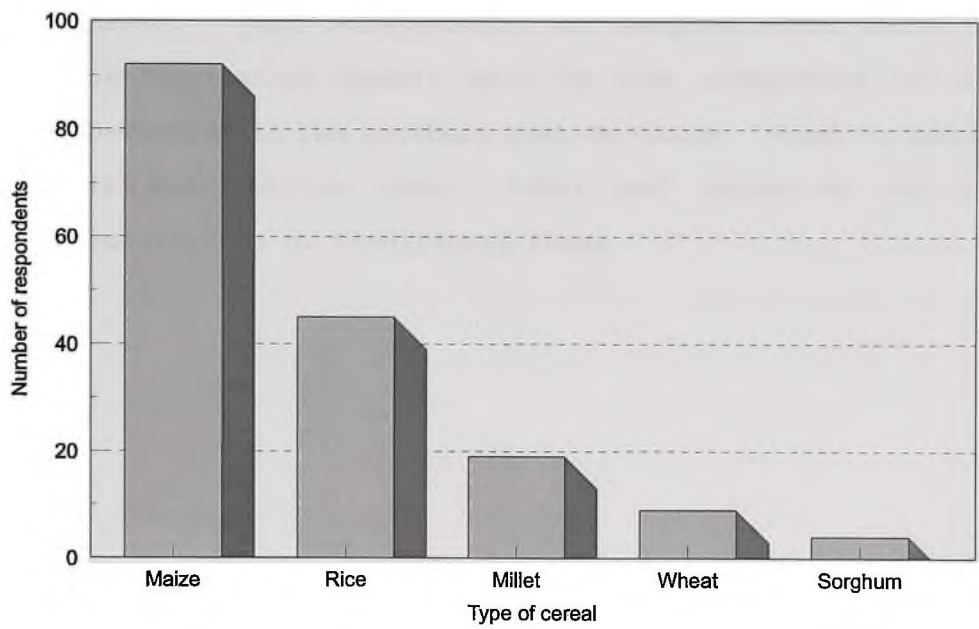
Nearly all of these mothers (96.4%), a hundred and eight in all, indicated a willingness to pay more money for a product of this nature, that is more than the equivalent weight of raw cowpeas would cost on the market.

Some of the mothers who did not feed cowpeas to their children in the home used industrial processed weaning foods including Vitalmix; a cereal/legume blend which has cowpea as one of its ingredients . This implies that some of the mothers who do not incorporate cowpeas into food given to their infants may be prepared to use it in the processed form as in proprietary weaning formulations. More than half of mothers fed proprietary foods to their infants during the weaning period. The products mentioned included *Cerelac* , *Babeena* and *Vitalmix*. These respondents indicated that these products were stored for a maximum of four weeks after the seal of the product was broken. A similar shelf-life period was indicated to be desirable for any proposed ready-to-eat infant formula by 95.8% of the mothers who responded positively to the idea of a processed cowpea flour being available on the market. The remaining fifteen respondents opted for a longer lasting product.

4.1.3 Preferences indicated for various cereals in a cereal-legume blend.

When asked which cereal they would prefer in a cowpea-cereal infant formulation, the mothers indicated a minimum of one and a maximum of three cereals. Ninety-two (92) of the mothers indicated maize; forty-five (45) indicated rice; nineteen (19) indicated millet; nine (9) indicated wheat and four (4) indicated sorghum (Fig. 7).

Fig. 7 Preferences indicated for various cereals in a cereal
 legume blend

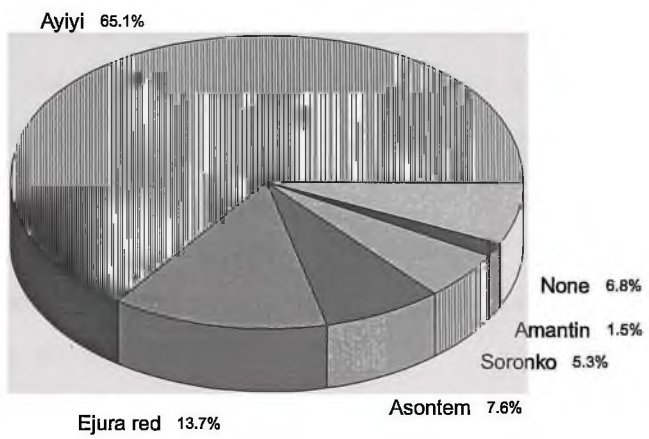


Maize was the popular choice since it is a staple that is grown widely in different parts of the country. Though rice is not widely cultivated in Ghana, it is imported and sold at a cheaper price than rice cultivated locally therefore it is affordable to a wider socio-economic group. Sorghum and millet were not popular choices probably because they are grown mainly in the north and are traditional staples for those who live in that region whereas maize is the cereal staple on which most traditional foods of both the northerners and southerners are based. The substitution of sorghum with maize for the production of cereal malt in the production of alcoholic beverages in the southern part of Ghana. Wheat is hardly grown in West Africa (Dako, 1983) and therefore not a common constituent of traditional foods.

4.1.4 Cowpea Variety Preferences indicated by respondents

Colour is an important preference characteristic of cowpea for farmers, traders and consumers (Dankyi,1993). The main colours of the common varieties being white, red and brown. Generally the white variety of cowpeas (Ayiyi) was preferred by 65.1% of the respondents to the red (Ejura Red), brown (Asontem and Soronko) and black (Amantin) varieties. Only nine of the mothers interviewed had no preferences for a particular variety of cowpeas (Fig. 8). The white variety was preferred for its colour, taste, tendency to soften quickly and because it was readily available in the market all year around. Some of the mothers said its colour allowed its incorporation into other foods without altering the original colour or imparting some undesirable colour to the food. The brown, red and black varieties on the other hand, were believed by some mothers to be more nutritious and to have a low susceptibility to insect infestation. Koura (1976), reported that the insect, *Callosobruchus maculatus*, a well known, primary pest of cowpea in Ghana, preferred black-eye cowpea to other varieties.

Fig. 8 Cowpea variety preferences



Though the pigmented varieties are known to have tannins in their seed coats, some traditional processing methods commonly used in the preparation of cowpea eg soaking, dehulling, etc. are known to reduce the polyphenol level to some extent (Desphande et al, 1982).

4.1.5 Characteristics mothers preferred in infant foods formulations

Some of the mothers interviewed (44.7%) preferred infant foods which had a light brown colour whilst others (46.2%) preferred milky coloured food (Fig 9). The remaining mothers had no colour preference for the weaning food they fed to their children. The majority of the mothers (84.8%) preferred to sweeten porridges that they fed to their infants. Most mothers used sugar whilst a few sweetened infant porridges with honey.

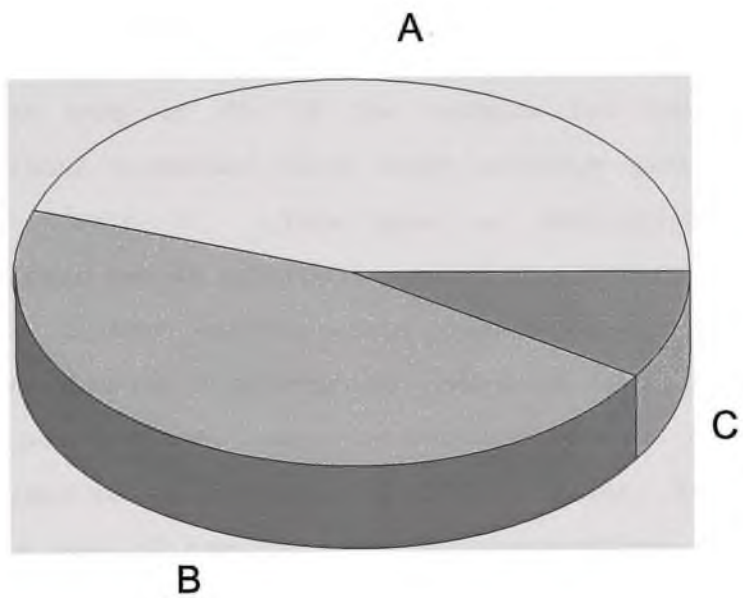
Mothers who had very young infants preferred a weaning gruel of a light consistency. The reasons given include the need for infant to be able to ingest and digest the food easily. The older infants were given gruels of relatively medium to thick consistency to ensure satiety.

Fig. 9 Colour preferences for infant foods

A = Light brown

B = Cream

C = No preference



A - Light brown
B - Cream
C - No preference

Though a few found this too inconvenient and time consuming a significant number, (90%) of the mothers preferred to prepare weaning porridge for their children from the basic ingredients if pre-cooked and/or partially cooked ingredients such as cowpea flour were available in the market. This response was however encouraging and suggested that the market existed for locally processed infant formulas in both ready-to-eat and semi-processed forms.

As many as 69% of the mothers fed their infants on traditional fermented maize dough porridge during the weaning period (Table 6). This gave an indication that though convenience was an attribute desired in the choice of an infant formula, as many mothers would prepare weaning porridges from raw ingredients. Most mothers indicated that fermented maize dough porridge was easy to prepare and in their opinion, nutritious enough for infant feeding purposes. Reasons such as, the low cost of the ingredients in comparison to value added imported and locally made infant porridges and the need for variety in the diet were other reasons that were given. Above all, some respondents admitted that fermented maize dough porridge was a natural choice over other traditional preparations probably because it was a commonly used a weaning gruel and a popular breakfast food. Fermented cereal porridges are commonly eaten in the country and since maize is a popular staple grown in the Southern parts, fermented maize dough is

more popular whereas millet and sorghum gruels are more commonly eaten in the northern parts of Ghana.

Table 6 Reasons for feeding fermented maize dough porridge to their children

Reasons	Number of Respondents	Percentage of Respondents
No Reason	42	31.8
Low cost and Convenience	21	15.9
Child likes it	13	9.8
Nutritious	10	7.6
On advice from clinic	6	4.5
Not applicable	40	30.3
TOTAL	132	100

Mothers who use proprietary weaning foods for their children were asked what motivated them to choose the particular food(s) they use currently. Mothers gave as many reasons as they wished (Table 7). Nutritional value and cost of the food were the most common answers received. The mothers who were illiterate explained nutritional value as the tendency of another child previously fed on that particular food to have gained weight and remained healthy. Some literate mothers said that when choosing a new brand of proprietary food, they compared the nutrition information on the package of the new brand to the one they were currently using. They selected the new one only if the nutrient content indicated was improved with respect to protein, vitamins and minerals. Convenience was also

a reason why mothers purchase proprietary weaning foods for their infants and the child's acceptance of the food, in some cases maintained its continued use.

Table 7 Motivating factors that control the purchase of proprietary weaning foods.

Reasons	Number of Respondents
Nutrient value	49
Cost	43
Convenience	15
Expiry date	14
Child likes it	9
No reason	8
Not Applicable	13

4.1.6 Sensory evaluation of some quality characteristics in weaning foods

Sensory evaluation was conducted with the mothers because they are the infant food purchasing population. It was aimed at finding out the mothers' perceptions of the infant foods texture, colour and consistency. Many biases due to the difference in the ages of the infants of the mothers evaluating the product for desirable consistency were noted. The respondents were given the opportunity to evaluate coded samples of a variety of proprietary infant foods- *Cerelac*, *Nutrend*, *Babeena* and *Frisocreme* (prepared for a six month old infant as directed on the package) and two traditional weaning porridges- fermented maize dough porridge (*koko*) and roasted maize flour

porridge (*Tom brown*). Subjects were requested to arrange these samples in order of preference or degree of acceptability with respect to texture, colour and consistency (one attribute at a time). The porridges were given scores 1 to 6, 1 indicating the most preferred and six representing the least preferred porridge) and the average response to each sample was calculated. Friedmann's tables was used to analyze the data.

Results of the sensory evaluation revealed that with respect to colour, Babeena and Frisocrema were the most preferred. Both infant formulas are milky in colour whilst cerelac the next preferred had a light brown colour. A significant dislike for the colour of fermented maize dough porridge, which was a popular gruel fed to infants of 69.7% of the mothers present, was indicated. This could mean that colour was not a major determinant in the mothers' choice of weaning food for their child. This is because more than two-thirds of the respondents fed a porridge to their infants whereas the same group of mothers expressed a significant dislike for its colour. Cost was probably a major factor as revealed earlier.

More mothers chose Frisocrema as a first choice in terms of texture, that is smoothness or particle size as reflected in the prepared mixture. Frisocrema made the smoothest porridge preferred. The more granular preparations such as Babeena and Roasted maize porridge were least preferred.

4.2 Effect of cereal malt on the viscosity of fermented maize dough

4.2.1 Product Description

The products formulated were free flowing flours. Sorghum malt imparted a reddish tinge to the fermented maize dough, whilst maize malt containing blends were slightly darker than fermented maize flour. The colour intensity of the blends increased with increasing malt concentrations. Millet malt did not have any visible effect on the colour of fermented maize dough.

4.2.2 Brabender Viscoamylograph viscosity indices

The Brabender viscoamylograms present useful information on the hot and cold paste viscosity characteristics of starch based foods.

The effectiveness of cereal malt in reducing bulk or increasing the caloric density of traditional fermented maize gruels, depends largely on the activity of the constituent amylases or on their potential to breakdown polysaccharides in the fermented maize dough. The effectiveness of sorghum, millet and maize malt incorporated into a 3-day fermented maize dough at 5% and 10% concentrations was investigated using the Brabender Viscoamylograph to measure the cooked paste characteristics of the fermented maize dough-cereal malt mixtures. The following indices were recorded for each sample: pasting temperature, peak viscosity, viscosity at 95°C and after

holding for 30 minutes (95°C-HOLD) and viscosity at 50°C and after holding for 20 minutes (50°C-HOLD).

4.2.2.1 Pasting temperature

Pasting temperature is indicated by the temperature at which the first detectable viscosity is measured by the amylograph. Pasting temperature was observed to decrease for fermented maize dough/millet malt blends when the sprouting time for millet malt was increased. This occurred both at 5% and 10% levels of malt concentration (Appendices 2, 3 & 4). A similar trend was observed in maize malt containing blends at the 10% concentration.

Increasing the time allowed for sprouting in sorghum preparation, from 2 to 3 days increased the pasting temperature of the blend produced with the malt, however for the 4-day sprouted sorghum containing mixtures, pasting temperatures were observed to be relatively low.

Statistical analyses of the results indicated that the type of cereal sprouted and the time allowed for the sprouting, significantly affected ($p \leq 0.05$) the temperature at which the samples pasted (Table 8). Significant interactions between the above factors indicated that the effect of the sprouting time allowed was dependent on the type of cereal malted.

Table 8 Significant F-values results for Analysis of Variance (ANOVA)

FACTORS	PASTING TEMPERATURE	PEAK VISCOSITY	VISCOSITY AT 95°C	VISCOSITY AT 95°C-HOLD	VISCOSITY AT 50°C	VISCOSITY AT 50°C-HOLD
Sprouting time (S)	27.324				10.618	7.119
Cereal type (C)	18.079	9.267	7.856	8.351	56.099	25.637
Malt concentration(M)					11.305	5.134
S x C	16.419					
S x M	-					
C x M	-		-	-	12.199	7.408

4.2.2.2 Peak viscosity

This index is linked to the ease of cooking of samples analyses. It is measured as the highest value of viscosity attained by the slurry during the heating cycle (25°C-95°C).

Generally the presence of malt in the fermented maize dough/ cereal blends seemed to decrease the viscosities. Similar observations were made by Akpapunam and Sefa-Dedeh (1994) with fermented maize dough/maize malt blends. Peak viscosity attained by maize malt containing blends were relatively low (Appendices 2,3 &4). Analysis of variance (ANOVA) indicated that malts of different cereals had significant effect on the peak viscosity of fermented maize dough (Table 8).

4.2.2.3 Viscosity at 95°C

The viscosity of the samples at 95°C were equivalent to their peak viscosities recorded for. For the blends containing 4-day millet, viscosities were drastically reduced from 320-

180BU and 100-40BU when the malt was incorporated at 5% and 10% levels respectively (Appendices 2,3 &4). Akpapunam and Sefa-Dedeh (1994) also reported the peak viscosity of fermented maize dough-maize malt blends to be equivalent to their viscosity measured at 95°C only after three days of fermentation.

ANOVA indicated that the type of cereal malted significantly affected ($p \leq 0.05$) the viscosity attained by the fermented maize dough/cereal malt mixture at 95°C (Table 8).

4.2.2.4 Viscosity at 95°C-HOLD

The viscosity attained by a sample after holding the temperature constant at 95°C for 30 minutes (95°C-HOLD) gave an indication of the ease of breakdown of the cooked paste. The addition of cereal malt to fermented maize dough was observed to decrease the viscosity at 95°C-HOLD (Appendices 2,3 &4). Viscosity of fermented maize dough-cereal malt samples at 95°C-HOLD are presented in Fig. 10.

Millet malt containing blends had the lowest viscosity when the malt had been sprouted for 4 days whilst the 2-day and 3-day millet malt containing blends had relatively high viscosities. Maize malt sprouted for 3 days seems to produce a greater viscosity reduction effect on fermented maize dough as compared to the 2-day and 4-day sprouted maize preparations.

Fig. 10 Effect of sprouting time on the viscosity of fermented
maize dough-cereal malt blends at 95°C-HOLD

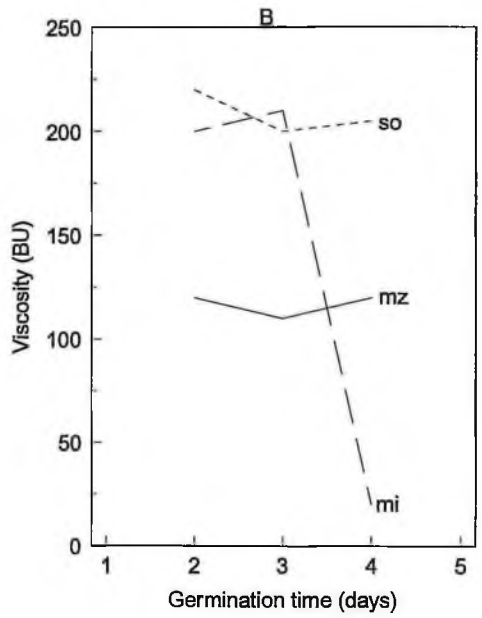
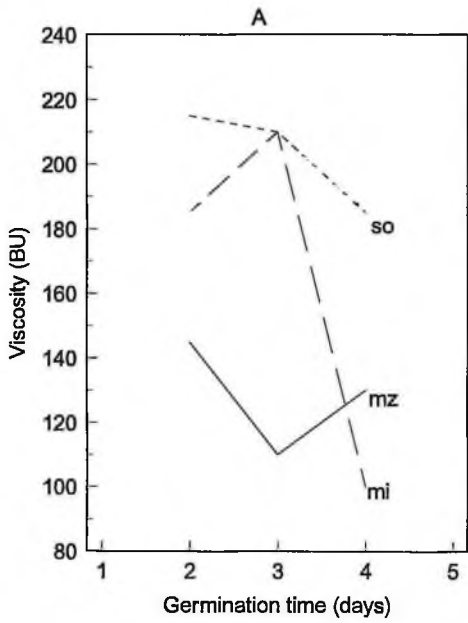
A = 5% cereal malt concentration in maize dough

B = 10% cereal malt concentration in maize dough

so = sorghum

mi = millet

mz = maize



4.2.2.5 Viscosity at 50°C

Viscosities measured at 50°C are most significant with respect to the eating quality of weaning foods as they reflect the eating consistency of the product.

During the cooling cycle (95°C to 50°C), the consistency of the fermented maize dough-cereal malt thickened considerably but to a lesser extent as compared to that of fermented maize dough to which no malt had been added (Appendices 2,3 & 4). The viscosities measured at 50°C for fermented maize dough/cereal malt mixtures are presented in Fig. 11.

When maize malt was incorporated into fermented maize dough at 5% level, the viscosity of the blend decreased. Sprouting for 2 days, 3 days and 4 days effected a percentage reduction of >50% in the viscosity of maize dough (Table 10). The viscosity reducing potential of of sorghum and millet was lowest for the 3 day sprouted samples. The 4 day sprouted samples had a greater viscosity reduction on maize dough (41% and 49.7% respectively) (Fig 11).

At 10% maize malt concentration in fermented maize dough, the activity of the malt appeared to decrease as sprouting was prolonged. The opposite trend was observed for the fermented maize dough-millet malt blends. The 4-day millet malt at 10% concentration in the blend drastically reduced the viscosity of the dough (86.9% reduction) (Table 9).

Fig. 11 Effect of sprouting time on the viscosity of fermented
maize dough-cereal malt blends at 50°C

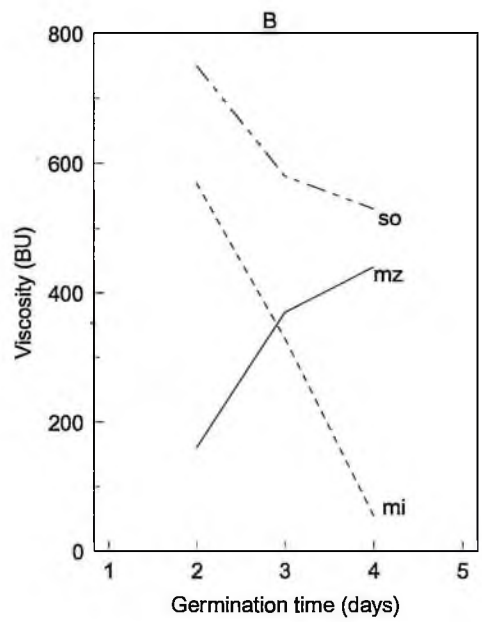
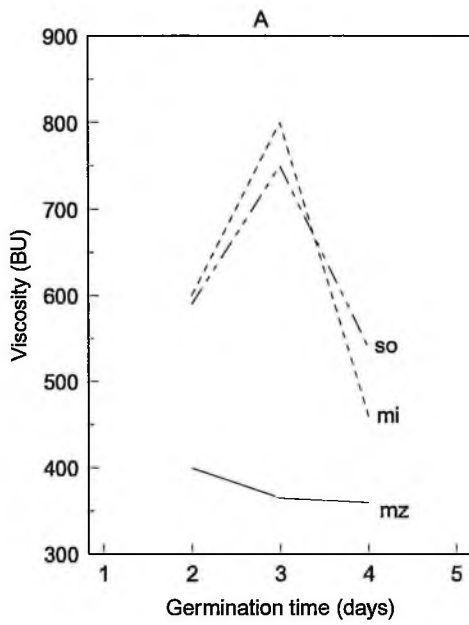
A = 5% cereal malt concentration in maize dough

B = 10% cereal malt concentration in maize dough

so = sorghum

mi = millet

mz = maize



Sorghum malt containing blends were thicker than the blends containing millet or maize malt. This suggests that the amylases in sorghum were comparatively less active at this temperature.

Results of viscosity measurements taken at 50°C suggest that the effect of incorporation (at 5% concentration) of maize malt and (at 10% concentration) of maize malt and 4-day sprouted millet malt is most desirable (Tables 9-11). These blends would produce weaning gruels of at least consistency and therefore high bulk density. The cereal malts under the above conditions produced more than fifty percent reduction in the viscosity of fermented maize dough.

Analysis of variance indicated that all the process variables; sprouting time, malt concentration and the type of cereal sprouted significantly affect the viscosity of the fermented maize dough/cereal malt blends at 50°C. Significant interaction between cereal type and malt level were indicated (Table 8).

Table 9 Effect of millet malts on cooked paste viscosity of fermented maize dough at 50°C and 50°C-HOLD

SPROUTING TIME (DAYS)	LEVEL OF MALT (%)	VISCOSITY REDUCTION (%)	
		50°C	50°C-HOLD
2	5	34.4	*
3		12.6	17.6
4		49.7	4.2
2	10	33.3	*
3		25.7	54.6
4		86.9	69.7

* - No reduction in Viscosity

Table 10 Effect of maize malts on Cooked Paste Viscosity of fermented maize dough at 50°C and 50°C-HOLD

SPROUTING TIME (DAYS)	LEVEL OF MALT (%)	VISCOSITY REDUCTION (%)	
		50°C	50°C-HOLD
2	5	56.3	12.6
3		60.1	49.6
4		60.6	27.7
2	10	57.4	31.1
3		56.3	42.8
4		48.6	36.1

Table 11 Effect of sorghum malts on Cooked Paste Viscosity of fermented maize dough at 50°C and 50°C-HOLD

SPROUTING TIME (DAYS)	LEVEL OF MALT (%)	VISCOSITY REDUCTION (%)	
		50°C	50°C-HOLD
2	5	35.5	*
3		18.3	*
4		41.0	*
2	10	7.1	*
3		25.7	0.84
4		29.0	*

* No reduction in Viscosity

4.2.2.6 Viscosity at 50°C-HOLD

The viscosities of the blends were measured after keeping the temperature constant at 50°C for 20 minutes (50°C-HOLD). During this holding period, viscosities of all the blends showed an increase in viscosity (Fig. 13, 14 & 15).

Blends that had 5% maize malt concentration had the lowest viscosities at this temperature. The viscosity reducing effect of the 2-day and the 4-day maize malts was lower than that of the 3-day malt (Table 10). Maize malt that had been sprouted for three days reduced the viscosity of maize dough by almost 50%. Prolonged sprouting appeared to decrease the viscosity of reducing potential of the maize malt. The effect of millet malt incorporated into fermented maize dough at 5% concentration followed a similar trend as maize malt though it showed a relatively lower viscosity reduction effect on the maize dough (Fig. 12).

Increasing the concentration of maize malt in the blends improved its viscosity reducing effect on fermented maize dough, except in the case of the 3-day sprouted maize. The viscosity of fermented maize dough-millet malt blends decreased drastically with prolonged sprouting of the millet (4-day sprouting) (Fig. 12). The samples that had the lowest viscosities at this index were; at 10% malt concentration in fermented maize dough, the 3-day millet and maize malt containing blends and at 5% malt concentrations, the blends containing 3-day sprouted maize malt (Fig. 14 and 15). At 50°C-

Fig. 12 Effect of sprouting time in the viscosity of fermented
maize dough-cereal malt blends at 50°C-HOLD

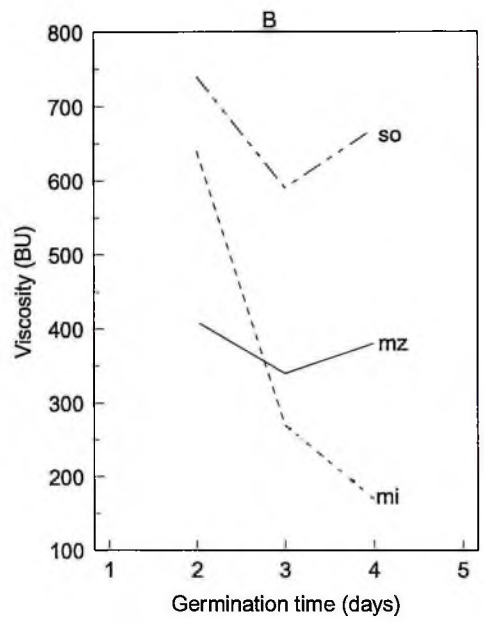
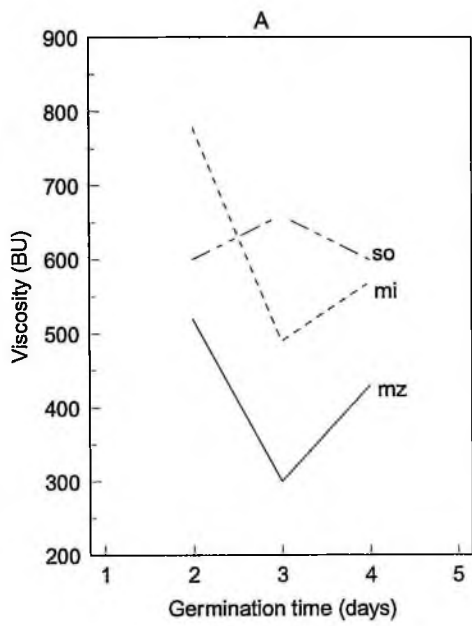
A = 5% cereal malt concentration in maize dough

B = 10% cereal malt concentration in maize dough

so = sorghum

mi = millet

mz = maize



HOLD the effect of sorghum malt on fermented maize dough was greatly inhibited. Some of the fermented maize dough-sorghum malt blends were observed to be thicker than fermented maize dough.

Statistical analysis indicated that the viscosity of fermented maize dough/cereal malt mixtures at this index is significantly affected ($p \leq 0.05$) by the type of cereal sprouted, the time allowed for sprouting and the level of malt incorporation into the fermented maize dough. There was significant interaction between the level of malt and the type of cereal malted (Table 8).

4.2.3 Effect of cereal type on the pasting characteristics of fermented maize dough-cereal malt blends

A closer look at a graphical representation of the amylograms of the fermented maize dough-cereal malt blends containing sorghum malt showed that in comparison with the malts of maize and millet, sorghum exerted a low viscosity reducing effect on fermented maize dough during the heating cycle (Figs. 13,14 & 15). During the cooling cycle viscosity of the blends increased and at 50°C, all the blends had a lower viscosity than fermented maize dough to which no malt had been added. On holding the temperature constant for 20 minutes some of the blends thickened to attain higher viscosities than fermented maize dough.(that is , at 50°C-HOLD).

Fig. 13 The effect of sprouted sorghum on the pasting characteristics of 3-day fermented maize dough

A = 5% cereal malt concentration in maize dough

B = 10% cereal malt concentration in maize dough

2 = 2 days of sprouting

3 = 3 days of sprouting

4 = 4 days of sprouting

c = control, no sprouting

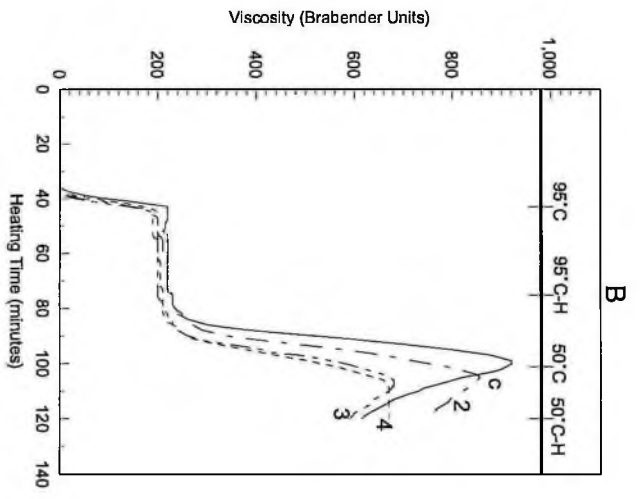
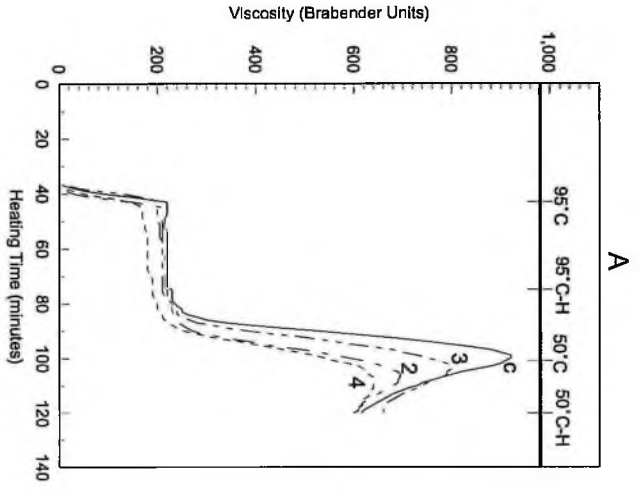


Fig. 14 The effect of sprouted maize on the pasting characteristics of 3-day fermented maize dough

A = 5% cereal malt concentration in maize dough

B = 10% cereal malt concentration in maize dough

2 = 2 days of sprouting

3 = 3 days of sprouting

4 = 4 days of sprouting

c = control, no sprouting

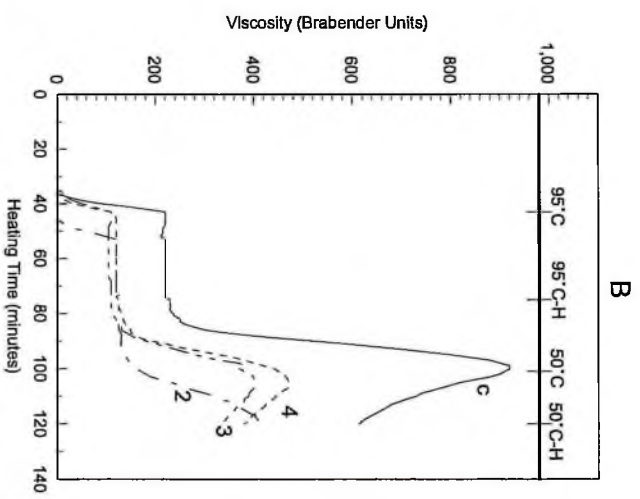
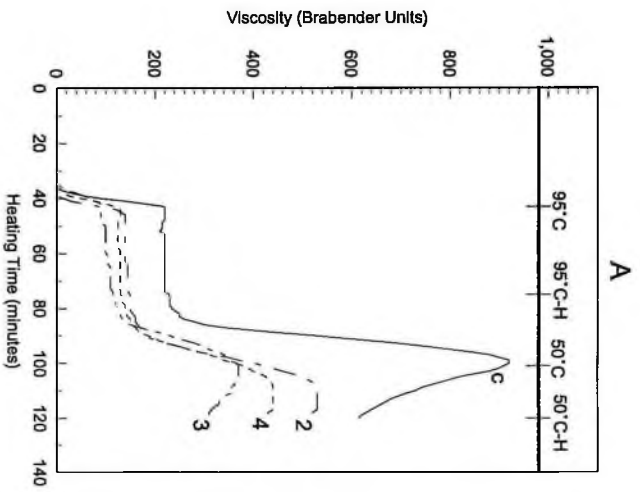


Fig. 15 The effect of sprouted millet on the pasting characteristics of 3-day fermented maize dough

A = 5% cereal malt concentration in maize dough

B = 10% cereal malt concentration in maize dough

2 = 2 days of sprouting

3 = 3 days of sprouting

4 = 4 days of sprouting

c = control, no sprouting

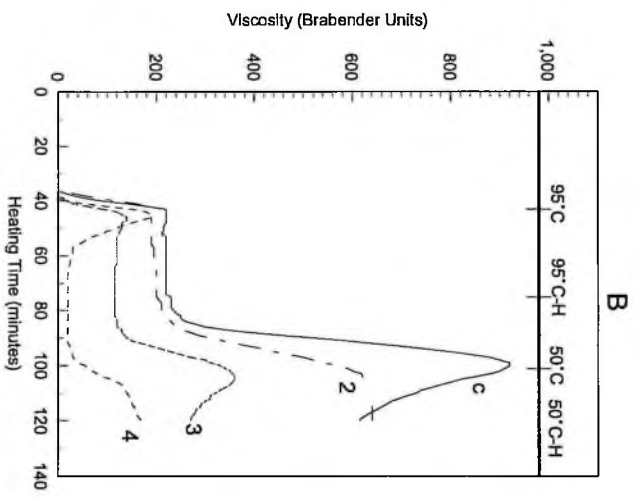
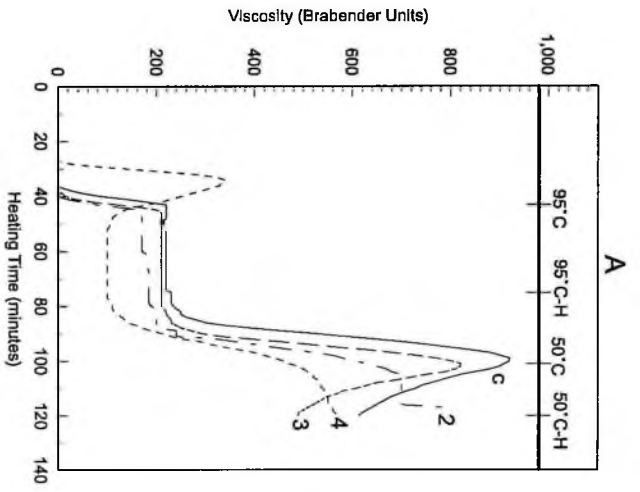


Figure 14 shows that blending maize malt with fermented maize dough, lowered both hot and cold paste viscosities. Sprouting maize for 3 days resulted in the lowest viscosities (at both concentration levels of 5% and 10%). When fermented maize dough/maize malt blends were analyzed.

The incorporation of 4-day sprouted millet into fermented maize dough at 5% concentration was observed to result in high peak viscosity and a markedly low pasting temperature of 69.3°C (Fig. 15). The addition of 10% malt to fermented dough resulted in a greater reduction in viscosity than 5% level of addition.

Statistical analysis of the viscosity indices measured indicated that the hot paste viscosities of the blends were significantly affected by the type of cereal malted (ie. peak viscosity, viscosity at 95°C and viscosity at 95°C-HOLD) whereas the viscosities at 50°C and 50°C-HOLD were significantly affected by all the three process variables investigated; type of cereal, concentration of malt in the blend and the time allowed for sprouting during malt preparation (Table 8). This gives an indication that the amylases in the different malts behaved differently at high and at low temperatures.

4.3 The effects of cowpea steaming and fermentation on the chemical and functional properties of maize-cowpea blends

4.3.1 Product Description

The fermented maize-cowpea blends prepared were cream-coloured flours. The blends which had been fermented appeared darker, with their intensity increasing with the duration of fermentation. However, cowpea addition had no visible effect on the colour of the blends.

4.3.2 Product composition

The results show that cowpea had a high ash content, whilst maize showed relatively higher fat content (Table 12).

Table 12 Chemical composition of cowpea and maize

	cowpea	maize
Moisture (%) ²	7.6812	4.9854
Protein (%) ^{1,2}		10.8935
Crude fat (%) ²	2.8634	3.8962
Ash (%) ²	3.7924	1.1637

¹ N x 6.24

² dry matter basis

4.3.3 pH and Acidity

The solid-state fermentation of maize dough had a drastic effect on pH. Within the first 24 h of fermentation the pH dropped from 6.3 to 4.0 (Fig. 16). After 72 h of fermentation the pH of the dough was 3.87. Fortification with up to 10% of unsteamed cowpeas yielded fermented dough with comparable pH as

Fig. 16 pH profiles: Effect of steam treatment and cowpea concentration on the traditional lactic acid fermentation of maize dough

A = unsteamed cowpea-fortification at concentrations of 0 - 20%

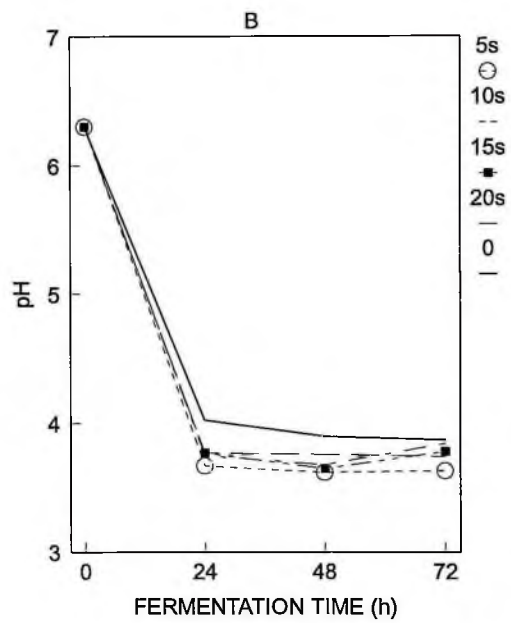
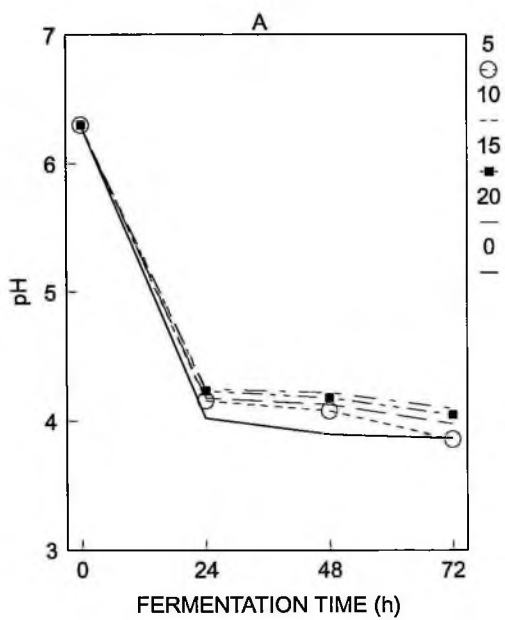
B = steamed cowpea-fortification at concentrations of 0 - 20%

5s = 5% steamed cowpea

10s = 10% steamed cowpea

15s = 15% steamed cowpea

20s = 20% steamed cowpea



the unfortified maize dough. Samples containing 15-20% cowpeas however showed a relatively high pH (Fig. 16). The proteins in the cowpeas may have contributed to the high pH.

Steaming of cowpeas prior to addition to maize appeared to promote fermentation (Fig. 16B). These samples had relatively lower pH than their unsteamed samples. Fortification up to 15% steamed cowpea provided samples with comparable pH as the 100% maize samples. The data suggests that maize may be fortified with cowpea up to 15% level and fermented to produce a dough of low pH.

Analysis of variance on the data showed that only fermentation time had a significant effect ($p \leq 0.05$) on dough pH. Duncan's multiple comparison tests indicated that the unfermented maize samples were distinctly different from the fermented samples. The samples fermented for 24 h were significantly different from those fermented for 72 h. The 48 h-fermented samples however compared favourably with the other two samples (Appendix 11).

The major carboxylic acids produced during the fermentation of maize dough have been identified as lactic, butyric, acetic and propionic acids (Plahar and Leung, 1982). The acidity of maize dough increased with fermentation. The addition of cowpea lowered the acidity of the maize dough (Fig.17). Steaming the cowpeas prior to addition to the maize lead to a higher production of acid during fermentation for 48 h. However, acidity dropped drastically during the final 24 hours of the fermentation period monitored (72 h). Analysis of variance on the data showed that fermentation time had a significant ($p \leq 0.05$) effect on acidity. In addition the acidity level associated with each fermentation time was dependent on whether the cowpea has been steamed (Appendix 12).

The ability of the cowpea-fortified maize dough system to ferment and produce acids comparable to the traditional maize dough system is beneficial. Mensah et al. (1990) reported that the antimicrobial properties of fermented maize dough due to acids produced during fermentation. This was reported to reduce the incidence of diarrhoea in infants consuming fermented maize porridge. The cowpea-fortified maize dough will have two important attributes, (a) antimicrobial properties and (b) high protein content. This will make it useful in the formulation of weaning foods.

Fig. 17 Effect of addition of cowpeas on acid production during traditional lactic acid fermentation of maize dough

A= unsteamed cowpea-fortification at concentrations of

0 20%

B = steamed cowpea-fortification at concentrations of

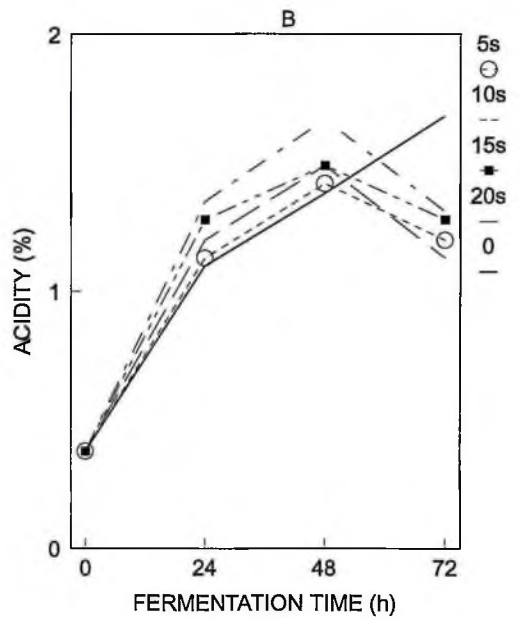
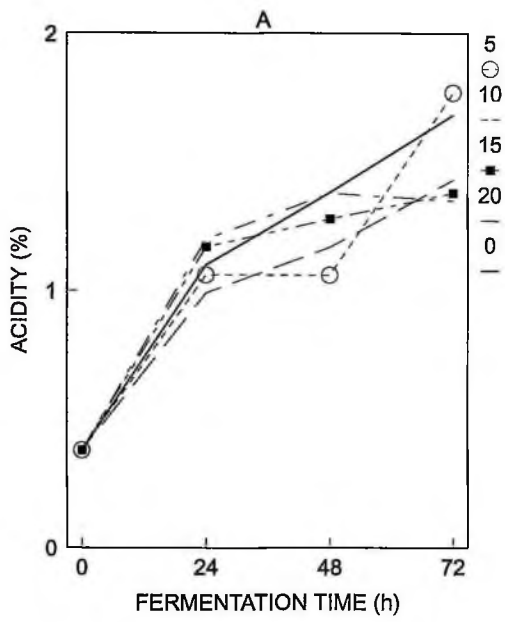
0 20%

5s = 5% steamed cowpea

10s = 10% steamed cowpea

15s = 15% steamed cowpea

20s = 20% steamed cowpea



4.3.4 Sugars and oligosaccharides

4.3.4.1 Cowpea

Xylose, fructose, glucose, galactose, sucrose, maltose, raffinose and stachyose were determined in different concentrations in whole cowpea (Table 13). Dehulling lead to an increase in the concentration of all sugars except for maltose, glucose and galactose. This suggests that maltose, glucose/galactose are concentrated in the seed coat. Steam treatment of cowpeas lead to a decrease in almost all the sugars with the exception of sucrose, glucose and galactose.

The α -galactosides are known to constitute the major portion of sugars in legume seeds (Fleming, 1980), Stachyose was observed to be the major oligosaccharide, followed by raffinose in the cowpea samples as reported by other workers (Akpapunam and Markakis, 1979; Abdel-Gawad, 1992; Sosulski *et al*, 1982). The levels of stachyose and raffinose increased with dehulling. This observation was contrary to reports by other workers (Akinyele and Akinlosotu, 1991) who detected a decrease in oligosaccharide levels after dehulling cowpea seeds. The longer pre-soaking period of 4 hours allowed in their experiment may have facilitated leaching or initiated the process of fermentation in the seed resulting in α -galactosidase activity on the oligosaccharides.

Table 13 Levels of mono-, di-, oligosaccharides determined in cowpea (*Vigna unguiculata*) samples (mg/100g dry matter)

COWPEA SAMPLES	XYLOSE	FRUCTOSE	GLUCOSE+				STACHYOSE
			GALACTOSE	SUCROSE	MALTOSE	RAFFINOSE	
WHOLE	0.380	0.012	0.337	1.652	0.118	0.552	2.545
DEHULLED	0.612	0.436	0	1.828	0.051	0.630	3.661
DEHULLED & STEAMED	0.332	0.068	0.028	2.034	0.039	0.234	3.340

4.3.4.2 Maize

Maize was observed to have high concentrations of glucose and galactose. Other sugars detected in the maize were xylose and fructose (Table 14). The effects of fermentation on the concentration of the sugars varied. During the first 24 hours of fermentation, the concentration of fructose and glucose and galactose decreased. Xylose and maltose however showed a slight increase in concentration. Further fermentation for 24 h showed an increase in all the sugars except xylose. fermentation for 72 h showed a drastic reduction in the concentration of glucose/galactose and maltose (Table 14). The levels of maltose, glucose and galactose appeared to increase during the first 48 hours of fermentation and then drop drastically after 72 hours. Sucrose, raffinose, and stachyose were not detected in the maize samples.

Table 14 Levels of mono- and disaccharides as determined in maize (*Zea mays*) samples (mg/100g dry matter)

MAIZE SAMPLES	FERMENTATION TIME/HRS	XYLOSE	FRUCTOSE	GLUCOSE +	
				GALACTOSE	MALTOSE
	0	0.705	1.093	9.636	0.210
	24	0.788	0.678	9.566	0.277
	48	0.481	0.690	10.213	0.438
	72	0.473	0.597	1.056	0.140

4.3.4.3 Fermented Maize-Cowpea Blends

4.3.4.3.1 Co-fermentation

Fermented maize and cowpea blends showed varied effects of process variables on sugar and oligosaccharide concentration. In the system in which cowpea was co-fermented with maize (Figs. 18 & 19) the effects of process variables on xylose concentration was not conclusive. Xylose was derived from both the maize and cowpeas. The co-fermentation of maize with steamed cowpeas (10,15 and 20%) appeared to increase the xylose concentration (Figs.19 B,C & D) up to 48 h of fermentation after which a decrease was observed. The system containing unsteamed cowpeas however showed a consistent decrease in xylose concentration with the 20% cowpea-fortified system (Fig. 18D). The sugars which are derived solely from cowpeas; sucrose, raffinose and stachyose seemed to be affected by fermentation. A general decrease with fermentation and complete removal were observed. The sugars predominantly from maize, i.e glucose/galactose (Fig.20), maltose and fructose (Fig.18 & 19) showed a general reduction with fermentation. Steaming of the cowpeas appeared to assist this reduction.

Fig. 18 Effect of fermentation on the sugar levels in co-fermented maize-cowpea blends

A = 5% unsteamed cowpea

B = 10% unsteamed cowpea

C = 15% unsteamed cowpea

D = 20% unsteamed cowpea

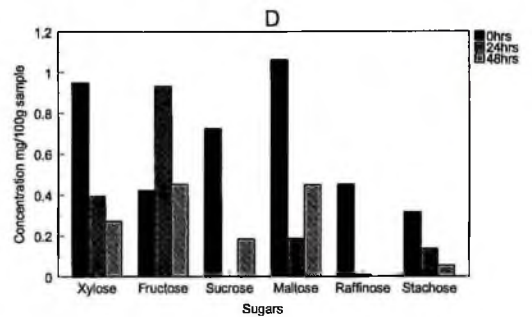
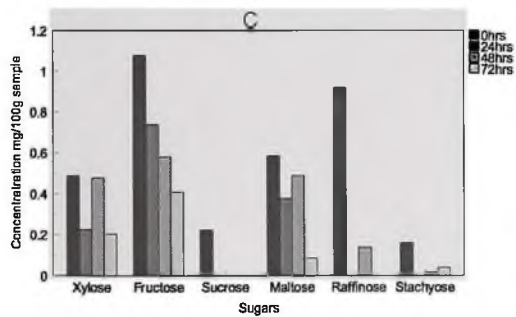
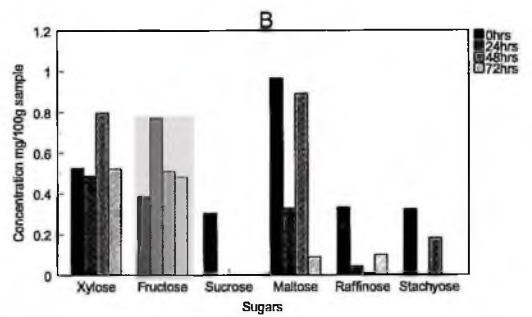
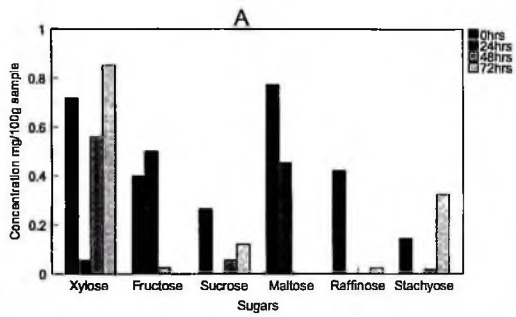


Fig. 19 Effect of fermentation on the sugar levels in co-fermented maize-cowpea blends

A = 5% steamed cowpea

B = 10% steamed cowpea

C = 15% steamed cowpea

D = 20% steamed cowpea

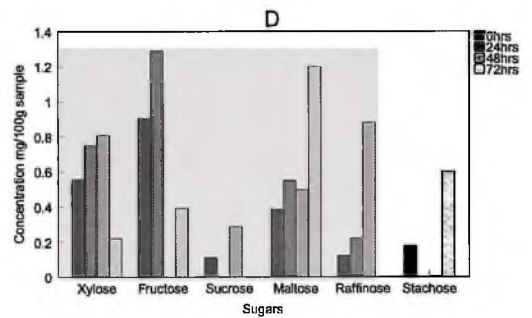
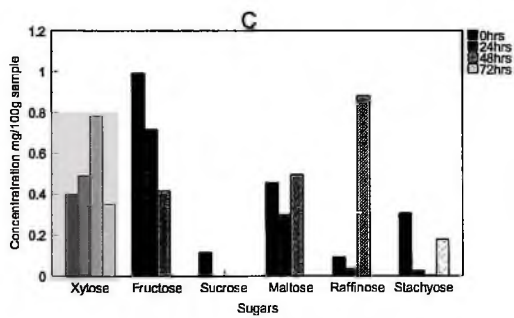
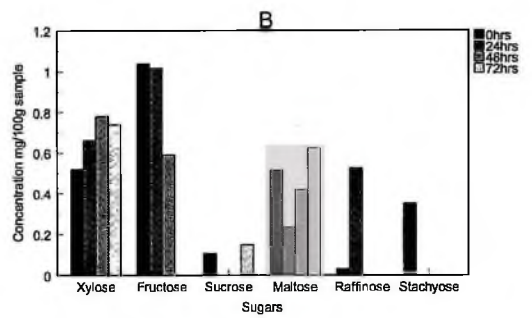
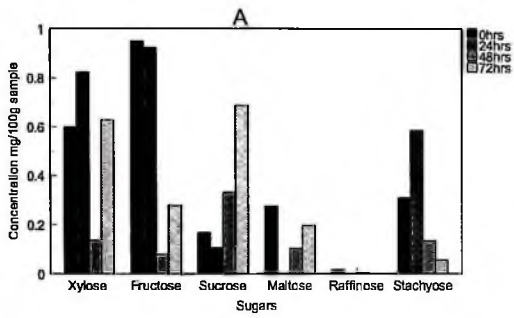
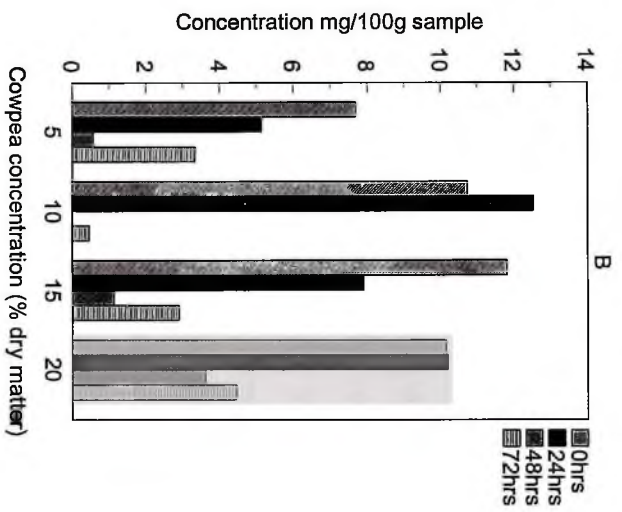
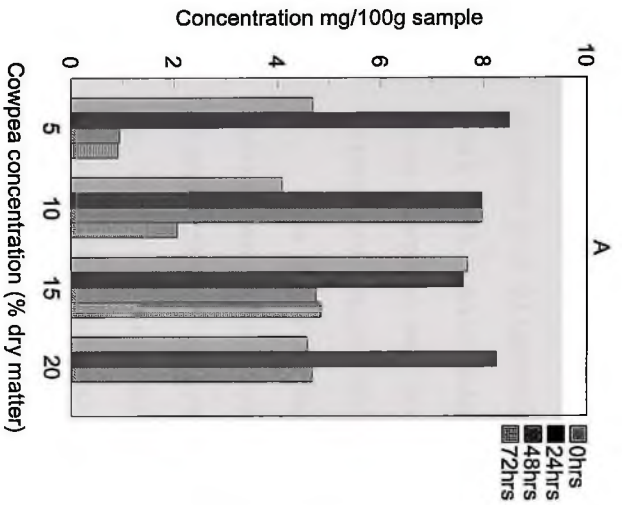


Fig. 20 Effect of fermentation on glucose concentration in co-fermented maize-cowpea blends

A = unsteamed cowpea-fortified blends

B = steamed cowpea-fortified blends



4.3.4.3.2 Blend after maize fermentation

This system showed an interesting trend. Sugars such as sucrose, raffinose and stachyose derived solely from cowpeas showed great reduction in concentration with fermentation time (Fig.21 & 22). This reduction was more pronounced in the 5, 10 and 15% cowpea-fortified fermented maize system. Apart from xylose, all other sugars i.e. glucose/galactose (Fig.23), fructose and maltose showed a general reduction with process variables. The data suggest that the fermented maize dough with its 50-55% moisture is an important media for the reduction of sugars and oligosaccharides derived from cowpeas. It is proposed that the reactions involving the sugars and oligosaccharides from cowpeas may have occurred from the time of mixing with the fermented maize dough to the early part of drying at 65°C.

The data from the two fermented maize-cowpea systems was subjected to analysis of variance. Table 15 is a summary of the significant F-values from the analysis. Xylose was not affected by any of the process variables. Fermentation time had a significant effect on fructose, glucose/galactose, maltose, raffinose and stachyose concentrations (Table 15). The level of cowpeas in the blend affected the glucose/galactose and stachyose concentrations. Steam treatment affected only the maltose concentration. Significant interactions were found between fermentation time and all other process variables.

Fig. 21 Effect of fermentation on the sugar levels in
fermented maize-cowpea blends

A = 5% unsteamed cowpea

B = 10% unsteamed cowpea

C = 15% unsteamed cowpea

D = 20% unsteamed cowpea

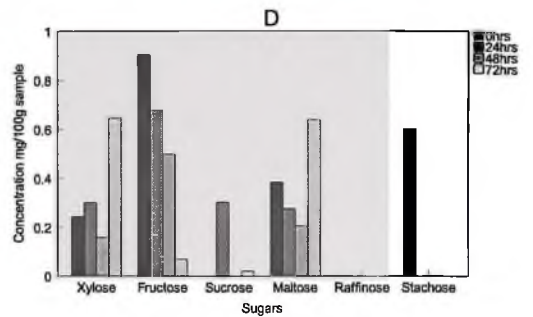
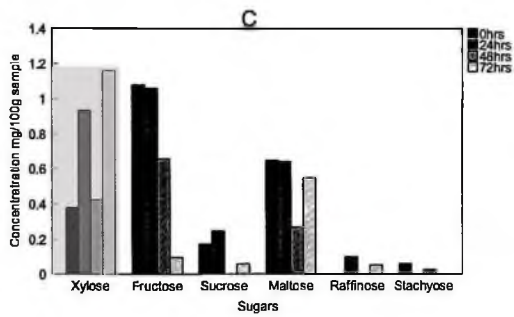
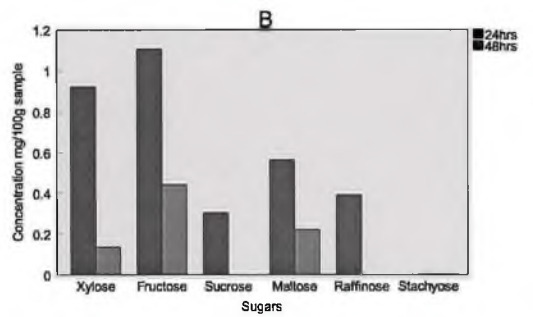
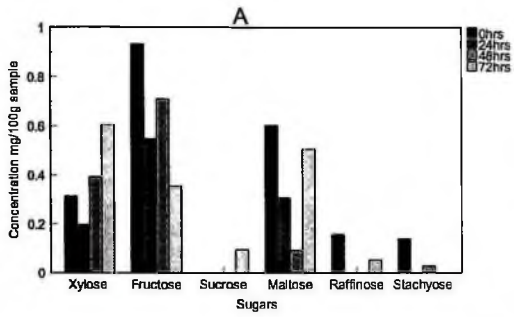


Fig. 22 Effect of fermentation on the sugar levels in
fermented maize-cowpea blends

A = 5% steamed cowpea

B = 10% steamed cowpea

C = 15% steamed cowpea

D = 20% steamed cowpea

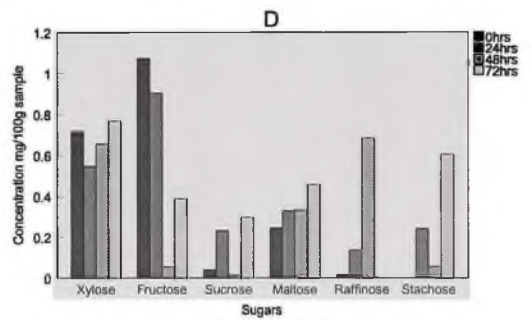
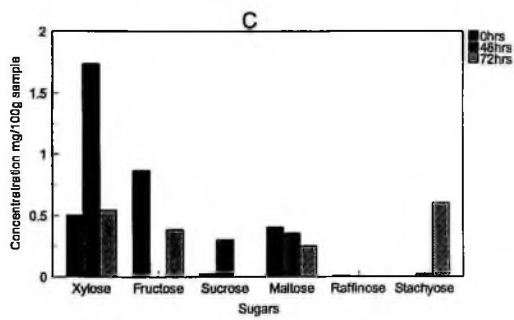
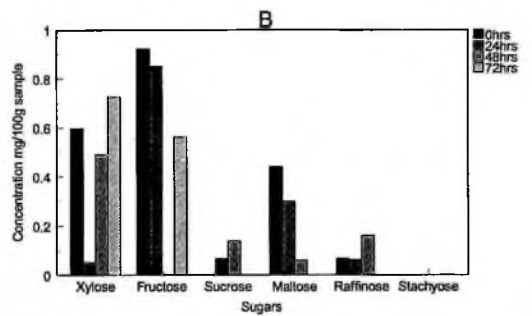
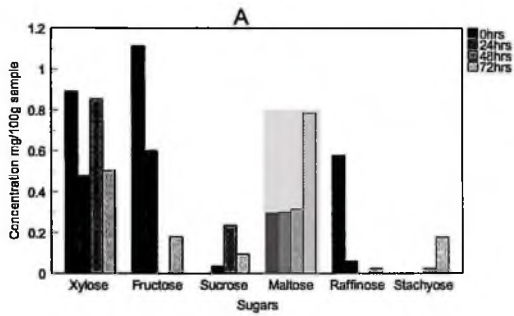


Fig. 23 Effect of fermentation on glucose concentration on
fermented maize-cowpea blends

A = unsteamed cowpea-fortified blends

B = steamed cowpea-fortified blends

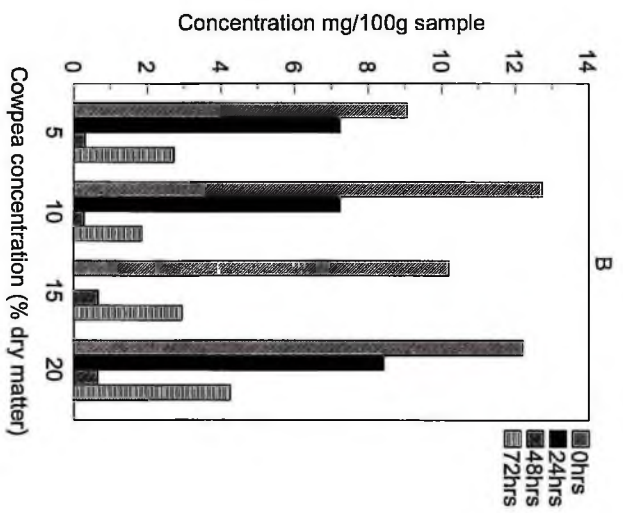
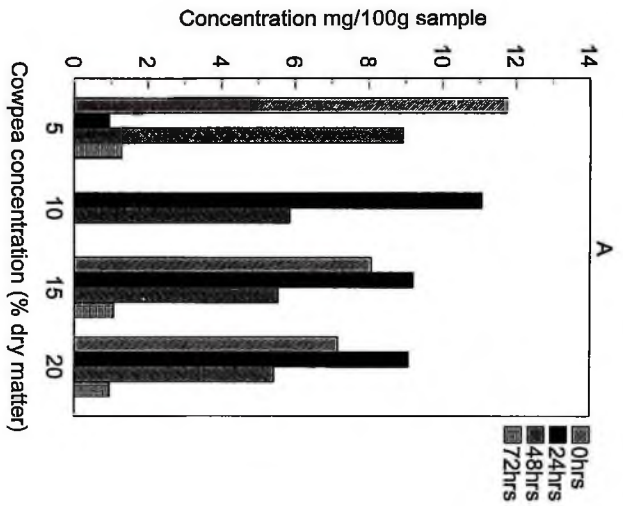


Table 15. Table of significant f-values

PROCESS VARIABLES	Fructose	Glucose + Galactose	maltose	Raffinose	Stachyose
Fermentation time	43.079	48.972	3.501	5.142	20.372
Fortification level		4.074			10.453
Steam treatment			5.400		
Fermentation time x Fortification level	2.767	3.746			9.392
Fermentation time x Steam Treatment	4.651	7.025		3.262	
Fermentation time x Method of Fermentation			3.753		
Steam x Method of fermentation	4.278				

4.3.5 Water Absorption Capacity

Process treatments of raw material are known to affect their hydration properties (Phillips *et al*, 1988). Water absorption capacity was measured at room temperature (26°C) to determine the behaviour of the cereal-legume flours in cold water. This is an important index which can give valuable information on the behaviour of the blend during processing.

Addition of cowpea improved the water absorption potential of fermented maize dough (Appendix 18). This was probably due to the influence of added protein in the blends. Proteins are mainly responsible for the bulk of water uptake and to a lesser extent the starch and cellulose at room temperature. Sefa-Dedeh and Osei (1994) made similar observations on a cowpea fortified fermented maize dough system.

Steam treatment of cowpeas was observed to increase its water absorption capacity from 166.8349% 221.9613%.

For the unfermented and 24-hour fermented maize-cowpea blends, steam treatment of cowpea seemed to cause a decrease in water absorption potential. However, after 48 hours and 72 hours

of fermentation the steamed cowpea fortified blends had higher water absorption capacities. Sefa-Dedeh and Demuyarko (1994) reported that steamed cowpea flour possessed better water absorption than raw cowpea flour.

The gelatinization of starch and the denaturation of protein that is the result of the application of heat treatment to cowpeas has been suggested to improve the water imbibing capacity of cowpea and mung bean proteins (Abbey and Ibeh, 1988; del Rosario and Flores, 1981).

Analysis of Variance indicated that cowpea fortification level and the method of fermentation applied significantly affected the water absorption capacity of the blends. The effects of steaming the cowpeas prior to its incorporation into the maize dough was not statistically significant (Table 16).

Table 16 Anova summary table for water absorption capacities of cowpea-maize dough blends

Source of Variation	SS	df	MS	F-ratio
MAIN EFFECTS	2240.6534	6	373.44223	5.891
replication	17.4044	1	17.40437	0.275
cowpea level	1290.4169	3	430.13897	6.786*
steam treatment	0.5816	1	0.58164	.009
mode of fermentation	937.1160	1	937.11597	14.783*
Residual	7607.7652	120	63.389710	
TOTAL CORR.	9847.4186	126		

4.4 The use of the Brookfield viscometer to measure the viscosity of cooked gruels and its comparison with the Brabender viscoamylograph.

The Brabender viscoamylograph and the Brookfield viscometer were used to determine the viscosity of the reconstituted fermented maize flours at concentrations of 6%, 8% and 10%. Viscosity measurements taken by the use of the Brabender viscoamylograph was observed to correlate significantly with viscosity measurements made on the same samples using the Brookfield viscometer at various spindle speeds (10, 20 and 50rpm). Regression models were developed to predict the Brabender viscosity of the samples. From the coefficient dependent variables; concentration, time and brookfield viscosities determined at the various spindle speeds. Coefficients of the variables in the models and their contribution to the observed response variabilities were summarized in Appendix 26.

Analysis of variance indicated that the concentration of the flour had a significant effect ($p \leq 0.05$) on viscosity measurements made using both instruments. The effect of temperature was not statistically significant.

4.4.1 Apparent Viscosity determined at 10 rpm

The model developed to predict viscosity (In Brabender units) at a spindle speed of 10 rpm could explain 95.32% of the variation in the viscosity (Appendix 26). The quadratic effect

of concentration was the most dominant variable, contributing 54.54% of the variation. The other critical variables were the temperature and the interaction between temperature and brookfield viscosity which contributed 18.98% and 21.80% respectively. Response surface plots of the model showing the relationship between brabender viscosity and brookfield viscosity are shown in figures 24 & 25.

At all solid concentrations brabender viscosity increased linearly with increasing brookfield viscosity (Fig. 24). For the same model, when solids concentration was constant at 6% (Fig. 25A) and 10% (Fig. 25B), the surface plots showed that slurry temperature did not seem to have any effect on brabender viscosities. However, at higher brookfield viscosities, increasing the slurry temperature increased the brabender viscosity (Fig. 25A & B). This suggests that Brookfield viscometer is more sensitive than the brabender amylographs for the measurement of viscosity at low temperatures.

Fig. 24 Models to predict Brabender viscosity from Brookfield viscosity at 10rpm, temperature and concentration of maize slurries

A = Temperature of 95°C

B = Temperature of 50°C

Regression equation:

$$Z = 54.964716 - 2.501844X_1 + 2.170264X_2 + 4.206249E-6X_1X_3$$

Z = Brabender viscosity

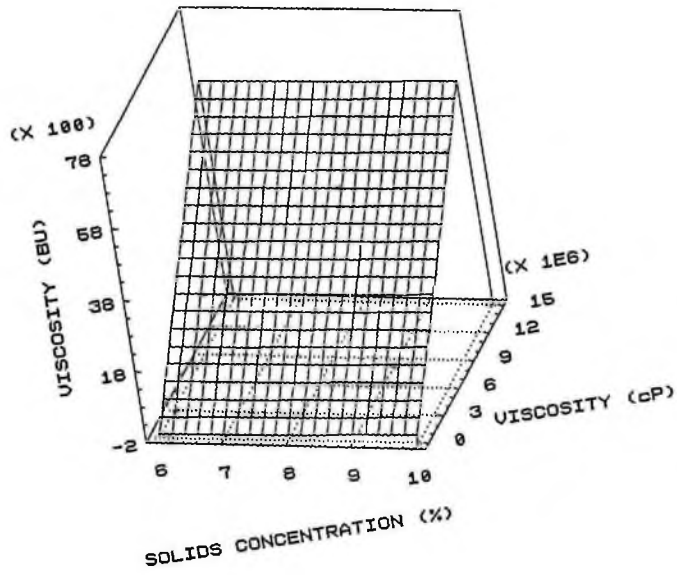
X_1 = Temperature

X_2 = Concentration

X_3 = Brookfield viscosity

$R^2 = 0.953278$

a



b

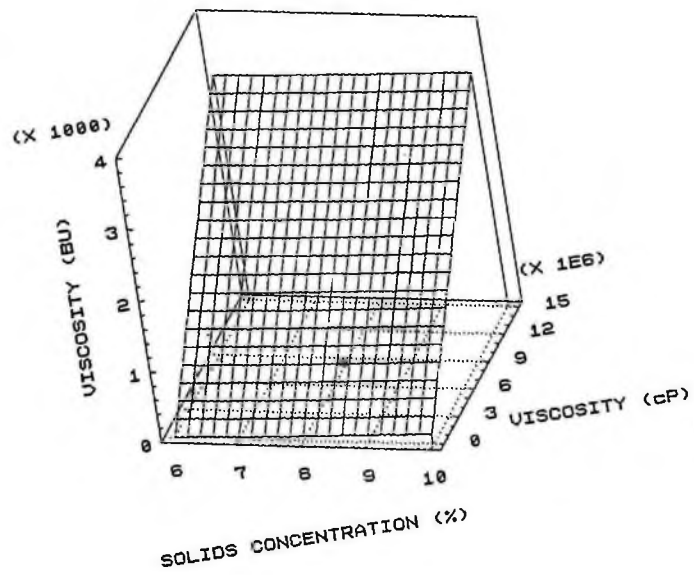


Fig. 25 Models to predict Brabender viscosity from Brookfield viscosity at 10rpm, temperature and concentration of maize slurries

A = Concentration of 6%

B = Concentration of 10%

Regression equation:

$$Z = 54.964716 - 2.501844X_1 + 2.170264X_2^2 + 4.206249E-6X_1X_3$$

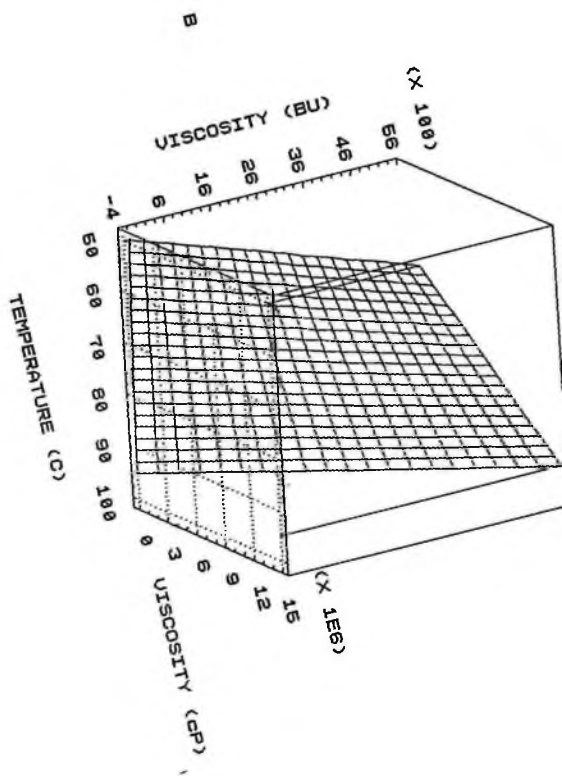
Z = Brabender viscosity

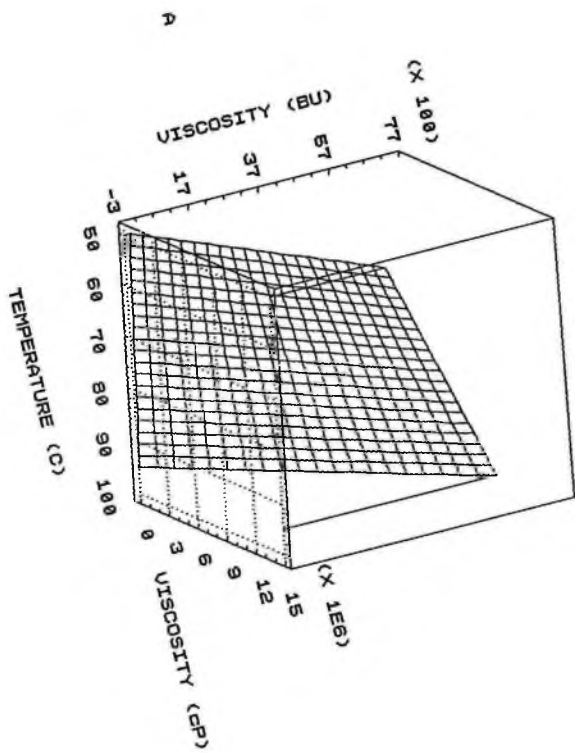
X₁ = Temperature

X₂ = Concentration

X₃ = Brookfield viscosity

R² = 0.953278





4.4.2 Apparent Viscosity determined at 20 rpm

At 20 rpm spindle speed , regression analysis of the process variables and viscosity measurements gave a model which could explain 95.35% of the variations in viscosity measurements.

The variables contributing most to the R^2 was the quadratic effect of concentration (54.54%) and the interaction between temperature and brookfield viscosity (40.35%). Interaction between concentration and brookfield viscosity also contributed 0.46% to the model.

Response surface plots based on the model (Figs. 26 & 27) showed that at both high and low temperatures (50 - 95°C) there was a linear relationship between brookfield and brabender viscosities. The effect of temperature on brabender viscosity was dependent on the brookfield viscosity (Fig.27). At low viscosities, solid concentrations seemed to have little effect on viscosities measures,(Fig.26) however as the sample solid concentration was increased, brabender viscosity was observed to be dependent on brookfield viscosities.

This implied that brookfield viscometer is more sensitive to changes in viscosity at lower temperatures and less sensitive to viscosity changes at low concentrations as compared to the brabender visco-amylograph.

Fig. 26 Models to predict Brabender viscosity from Brookfield viscosity at 20rpm, temperature and concentration of maize slurries

A = Temperature of 95°C

B = Temperature of 50°C

Regression equation:

$$Z = -16.932988 + 1.407992X_2^2 + 0.000026X_1X_3 - 0.000035X_2X_3$$

Z = Brabender viscosity

X₁ = Temperature

X₂ = Concentration

X₃ = Brookfield viscosity

R² = 0.953558

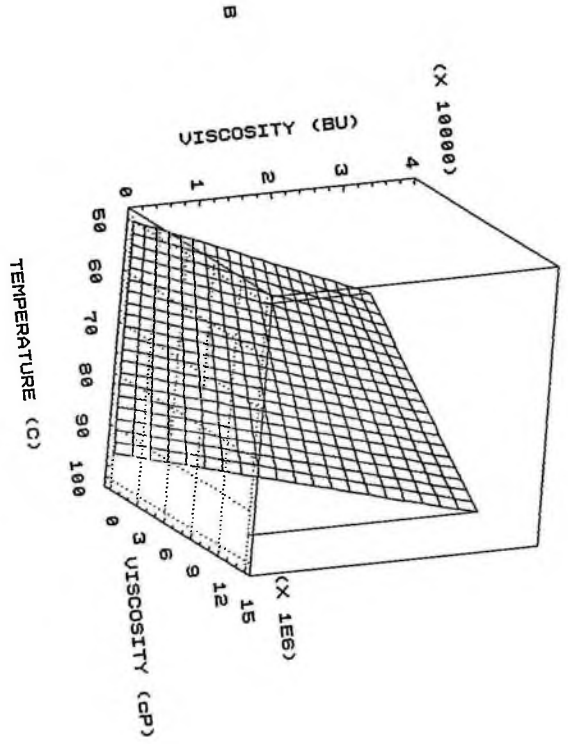
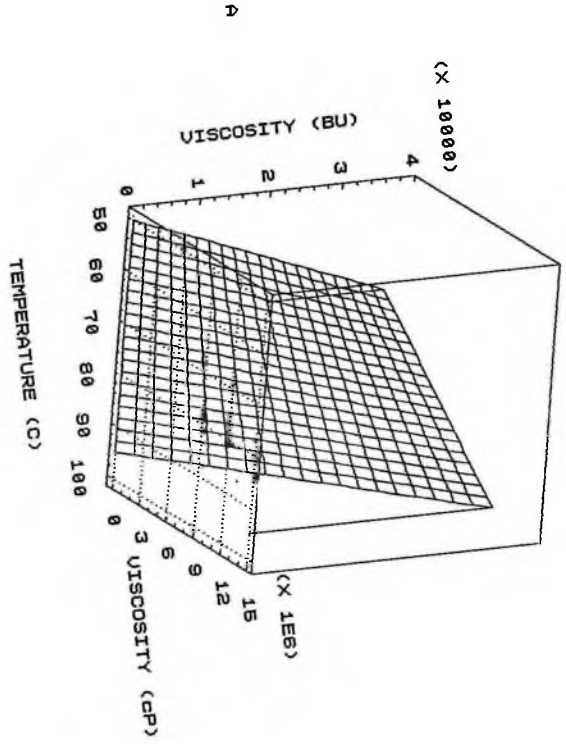


Fig. 27 Models to predict Brabender viscosity from Brookfield viscosity at 20rpm, temperature and concentration of maize slurries

A = Concentration of 6%

B = Concentration of 10%

Regression equation:

$$Z = -16.932988 + 1.407992X_2^2 + 0.000026X_1X_3 - 0.000035X_2X_3$$

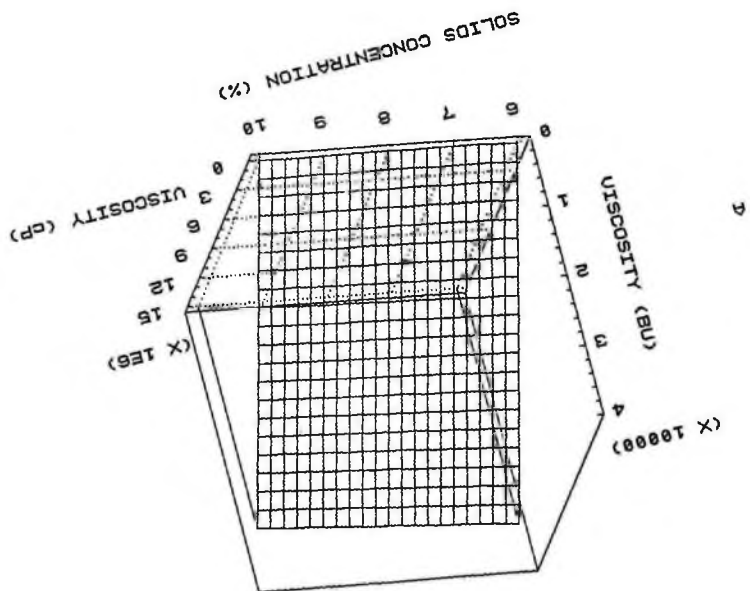
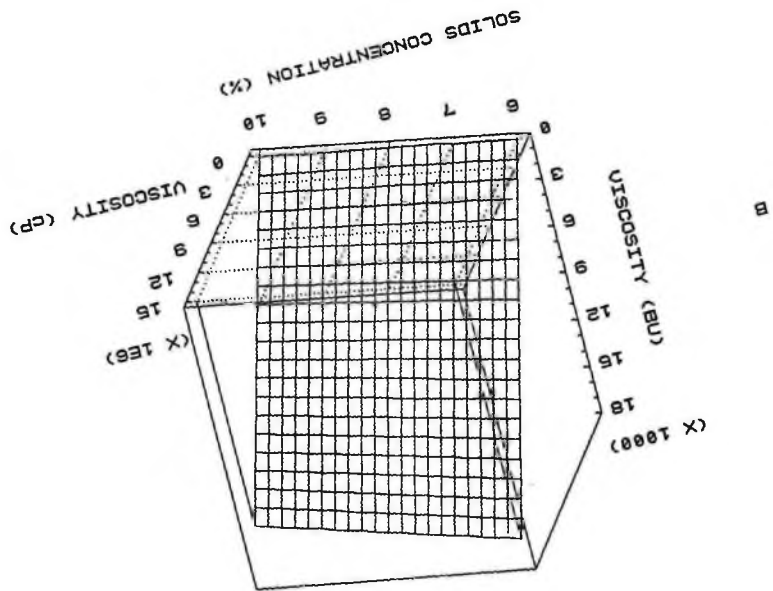
Z = Brabender viscosity

X₁ = Temperature

X₂ = Concentration

X₃ = Brookfield viscosity

R² = 0.953558



4.4.3 Apparent viscosity determined at 50 rpm

The regression model developed to predict viscosity (Brabender units) from concentration temperature and viscosity measurements taken at 50 rpm could explain 98.32 % of the variation. Brookfield viscosity was the most important variable contributing 92.49% to the R^2 . Other critical variables were the linear and quadratic effect of temperature and the interaction between brookfield viscosity and the process variable.

Response surface plots made from the model (Figs. 28 & 29) show a linear relationship between the viscosity measurement from both instrument. The effect of temperature and concentration on the brookfield and brabender viscosities was similar to that observed when brookfield viscosity measurements were taken at 20 rpm.

The results suggest that in spite of the difference in sensitivity there is a high correlation ($R = 0.8451$ 0.9597) between the viscosity measuring instruments. Therefore the brookfield viscometer which can be used to determine viscosity of smaller quantities of sample within a shorter time can be used to a high degree of accuracy.

Fig. 28 Models to predict Brabender viscosity from Brookfield viscosity at 50rpm, temperature and concentration of maize slurries

A = Temperature of 95°C

B = Temperature of 50°C

Regression equation:

$$Z = 1164.386945 + 0.004312X_3 - 57.189164X_1 + 0.704201X_1^2 + 0.000191X_1X_3 - 0.000808X_2X_3$$

Z = Brabender viscosity

X₁ = Temperature

X₂ = Concentration

X₃ = Brookfield viscosity

R² = 0.983238

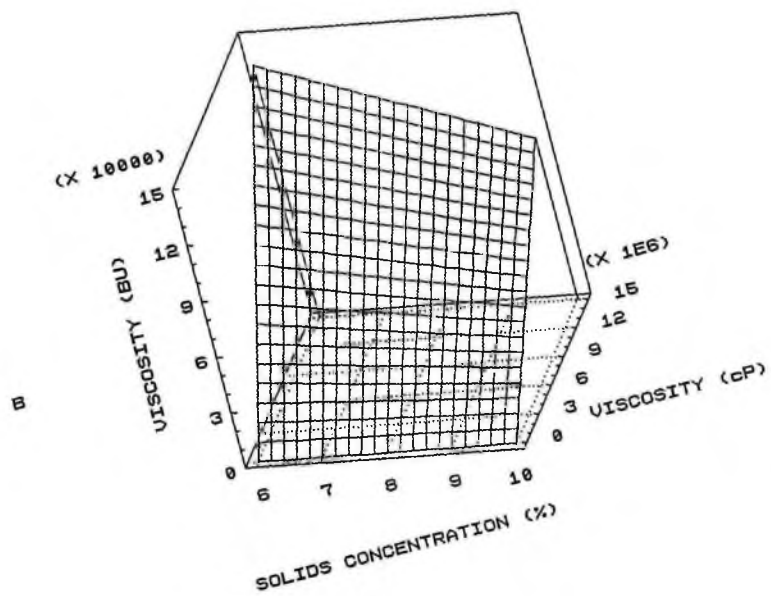
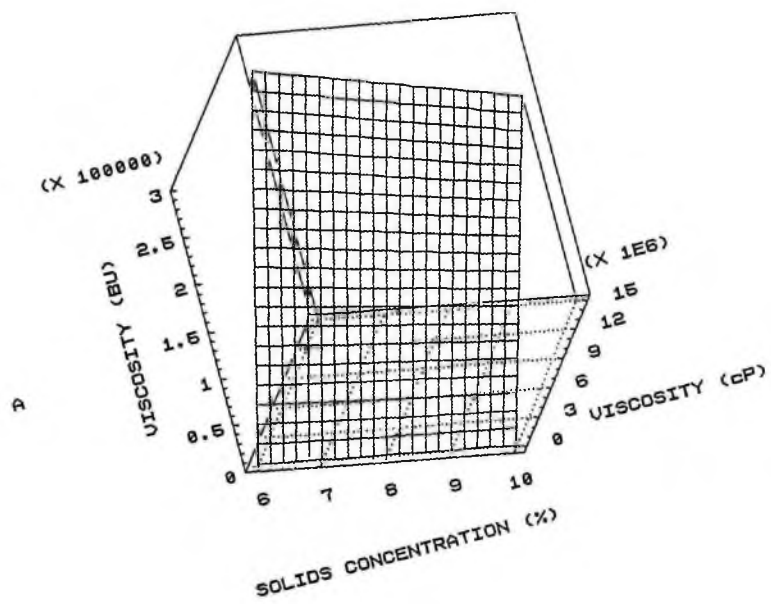


Fig. 29 Models to predict Brabender viscosity from Brookfield viscosity at 50rpm, temperature and concentration of maize slurries

A = Concentration of 6%

B = Concentration of 10%

Regression equation:

$$Z = 1164.386945 + 0.004312X_3 - 57.189164X_1 + 0.704201X_1^2 + 0.000191X_1X_3 - 0.000808X_2X_3$$

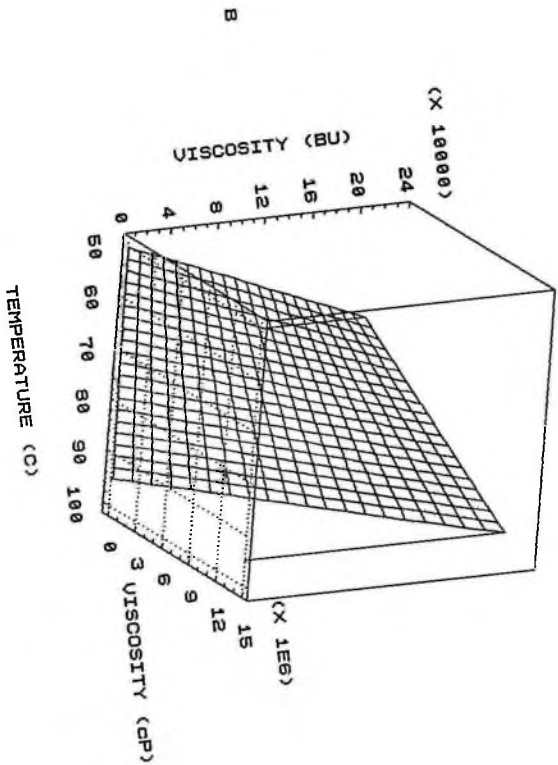
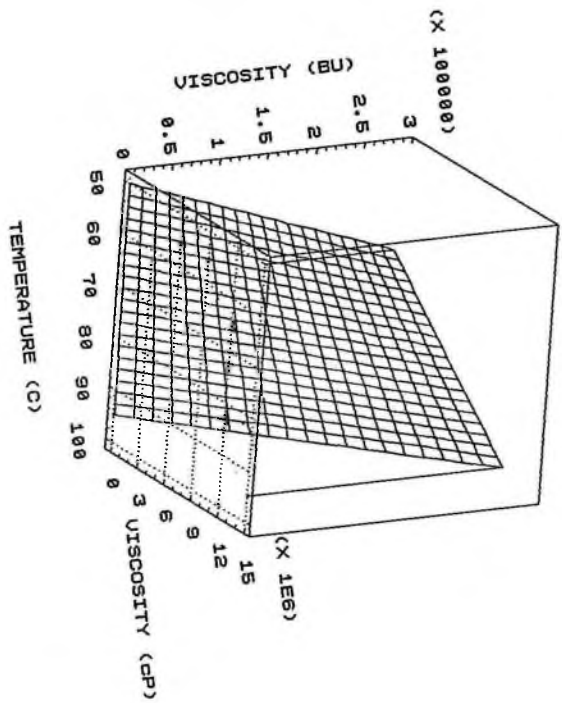
Z = Brabender viscosity

X₁ = Temperature

X₂ = Concentration

X₃ = Brookfield viscosity

R² = 0.983238



CONCLUSION

1. Though convenience is one of the factors that motivates mothers to purchase proprietary weaning foods, many mothers (%) prepared infant weaning porridges from raw ingredients eg. fermented maize dough. Majority of the mothers (>80%) were willing to incorporate raw or pre-cooked cowpea flour into foods prepared in the home for their infants and the rest of the family if such a product was available on the market. Among the many foods proposed, porridge was the most popular. It was observed that some of the mothers interviewed who were unwilling to introduce cowpeas into their infants diet, were feeding their infants proprietary weaning foods that contained some amount of cowpea (probably unknown to them) eg Vitalmix. These responses imply that a cowpea-cereal blend or cowpea flour product would find Market if it can be made to meet the expectations of the average mother.

2. Nutritional value and cost were the major contributory factors that motivated mothers to purchase a particular brand of infant formulation. The high protein content of the improved varieties of cowpeas and the relatively low cost of plant protein sources, would facilitate the production of a low-cost, but nutritious infant formulation.

3. Quality characteristics of infant porridges such as consistency, texture and colour varied widely. The consistency desired depended on the age of the infant. The mothers primary concerns were to enable the child to swallow the food easily and to ensure satiety. A wide variety of textures was acceptable to mothers; grainy and rough to smooth. acceptable colour ranged from milky to brown. Colour was not a major factor that controlled the mothers choice of a weaning food. This is because mothers expressed a significant dislike for the colour of fermented maize dough porridge which was currently being used by more than ninety percent (> 90%) of the mothers in feeding their infants.
4. The use of cereal malt can effectively decrease the viscosity of fermented maize dough. The addition of malt after the fermentation of the maize dough allows the action of the amylase to overcome the viscosity increasing effect of fermentation in cereals. Millet malt and maize malt markedly reduced the viscosity of fermented maize dough at 5% and 10% concentrations. the effect of the amylases increased with increasing sprouting time allowed.
5. Fermentation and steam treatment of cowpeas may be used to produce high-protein blends with reduced anti-nutritional

factors without a significant change in the pH and acidity profiles of the raw material (Fermented maize dough).

6. In spite of the difference in sensitivity of the Brookfield viscometer and the Brabender viscoamylograph, extremes of solids concentration and temperature, there was high correlation between the viscosity measurements taken by both instruments. The high R^2 derived from the regression models developed to predict Brabender viscosity from Brookfield viscosities at various spindle speeds implies that the Brookfield viscometer may be used to measure viscosity to a high degree of precision. This is of advantage as the Brookfield viscometer can be used to measure small amounts of sample and also instantaneous viscosity measurements may be made under a particular condition. However the Brabender amylograph is programmed to measure over a prescribed time setting. Both instruments have their uses and may be ideal for use in different situations.

RECOMMENDATIONS

1. There is need to carry out tests on the cowpea- maize blends to determine the occurrence of off-flavours and/or toxic compounds that may have been formed during co-fermentation of the maize-cowpea mixtures.
2. A study of the pasting characteristics of the fermented maize-cowpea blends after the addition of maize/millet malt would yield valuable information.
3. There is also the need to carry out microbiological studies to ascertain the effect of cowpea and cereal malt on the anti-microbial properties of fermented maize dough and fermented maize dough porridge.
4. Further work needs to be done to find out the factors that affect or control the mechanism of breakdown or release of sugars during fermentation in the maize-cowpea system.

The above recommendations for further study would facilitate the development of a safe, nutritious, low-cost infant formulation by the use of traditional technologies. This would improve the utilization of cowpeas, especially in infant feeding. This, with more studies could be used as an intervention to curb Protein Energy Malnutrition in children in the rural areas.

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APPENDIX 1

Dear Survey Participant, Madam, Miss, Mrs.

We are seeking your permission to ask you some questions concerning you family, your eating habits, your infant feeding practices and your preferences for certain quality attributes in infant foods. We are doing this not to criticize or embarrass you because we know how difficult it is to keep our children healthy and well fed. Rather, we want to do it as part of a study which will help us develop better foods for children and therefore benefit all the children of Ghana.

We promise that your answers to these questions will be kept confidential. That is, you and your child will not be identified as part of the survey to anyone else and you will be identified only by a code number to make sure this is true. I promise to carefully control access to this information and to use it only for the purposes we state in this letter.

If you agree to participate in this survey, please sign your name below or carefully state your agreement to the person who has given you this letter or read it to you. Thank you for your co-operation.

Sincerely,

Prof. S. Sefa-Dedeh
Department of Nutrition and Food Science
University of Ghana, Legon.

Participant Code _____

Signature of consenting
participant _____

Signature of witness
to oral or written consent _____

Signature of witness
to oral or written consent _____

UNIVERSITY OF GHANA
DEPARTMENT OF NUTRITION AND FOOD SCIENCE

PRODUCT DEVELOPMENT - FORMULATION OF A COST EFFECTIVE COWPEA
BASED WEANING FOOD

A survey of mothers' perceptions on the quality attributes
expected in a weaning food.

Date.....

Location.....

Background data

- 1. Mother's occupation.....
- 2. Highest level of education mother attained:
None[] Prim[] Sec[] Tech[] Univ[] Other[]
- 3. Number of children [] 4. Age of last child []

Section a

- 5. Do you incorporate cowpeas into the foods you give your children? y[]/n[].
- 6. If yes, how often ? Times a week.
- 7. If no, why not ?.....
.....
.....
- 8. In what form do you use cowpeas at home ?
.....
.....
.....
- 9. If you were given cowpea flour how would you use it?
y[]/n[].
- 10. Into which foods would you incorporate the flour?
.....
.....

11. Would you prefer a flour which has been pre-cooked and therefore cooks quicker than raw cowpeas? y[]/n[].
12. If cowpea flour is to be mixed with cereal, which will you prefer ?
maize[] sorghum[] rice[] wheat[] millet[]
13. Do you have preference for a particular cowpea variety for feeding your child? y[]/n[]
14. If yes, please give reasons.....
.....
.....
15. I have these cowpea samples, which of them would you want a weaning flour to be made from? (select one and give reasons)

CHOICE

REASONS

[]
.....
.....
.....

16. What colour do you think a weaning food should be?.....
.....
.....

17. Should weaning foods be sweetened.....or unsweetened.....?

18. What consistency should a weaning food have and why ?

CONSISTENCY

REASONS

9999

Light
.....
Medium
.....
Thick
.....

19. If the components were available, e.g. cowpea flour, would you make your own weaning foods at home? y[]/n[].

20. If no, why?.....
.....
.....

21. Which of these weaning foods do you use ?

FOODS	REASONS
Farex
Vitalmix/ Weanimix
Cerelac
Nutrend
Frisocreme
Others

22. What factors do you consider when purchasing a weaning food? (cost, convenience, nutrition information on label, size of package, expiry date, etc.).....
-
-
23. How long do you normally keep weaning foods after purchase? a package/tin.....()grammes lasts..... for
-weeks ordays.
24. Would you be willing to buy a pre-cooked cowpea product which costs slightly more than the same weight of the raw cowpea? y[]/n[]
25. What size of package would prefer ? Enough for 1[] 2[] 3[] other[] months.
26. What price would you be prepared to pay for a weaning food packaged for a single feeding ?cedis.

Section b

27. Arrange the following weaning foods in order of preference with respect to the following characteristics:

	1	2	3	4	5	6
CONSISTENCY						
COLOUR						
TEXTURE						

Appendix 2 Cooked paste viscosities of fermented maize- cereal malt blends

Type of cereal malted	malt level (%)	sprout time (days)	pasting temp (°c)	peak visc (bu)	visc 95°c (bu)	visc 95°c h (bu)	visc 50°c (bu)	visc 50°c h (bu)
maize	5%	2	84.2	140	140	145	400	520
Millet			87.5	170	170	185	600	780
Sorghum			83.3	210	210	215	590	600
Maize		3	85.5	90	90	110	365	300
Millet			82.7	200	200	210	800	490
Sorghum			84.2	190	190	210	750	660
Maize		4	80.9	130	130	130	360	430
Millet			69.3	320	100	100	460	570
Sorghum			82.0	170	170	185	540	600

Appendix 3

TYPE OF CEREAL MALTED	MALT LEVEL (%)	SPROUT TIME (days)	PASTING TEMP (°C)	PEAK VISC (BU)	VISC 95°C (BU)	VISC 95°C H (BU)	VISC 50°C (BU)	VISC 50°C H (BU)
MAIZE	10	2	80.4	120	120	120	160	410
MILLET			84.0	190	190	200	570	640
SORGHUM			83.6	190	190	220	750	740
MAIZE		3	81.8	110	110	110	370	340
MILLET			81.6	140	140	115	330	270
SORGHUM			85.6	190	190	200	580	590
MAIZE		4	83.2	110	110	120	440	380
MILLET			70.0	180	40	20	55	170
SORGHUM			80.2	190	190	205	530	670

Appendix 4

	FERMENTATION TIME (days)	PASTING TEMP (°C)	PEAK VISC (BU)	VISC 95°C (BU)	VISC 95°C H (BU)	VISC 50°C (BU)	VISC 50°C H (BU)
MAIZE DOUGH	3	84.9	200	200	225	915	595

Anova summary tables for Brabender viscosity indices

Appendix 5 Pasting temperature

Source of variation	SS	df	M.S.	F-Ratio
Main Effects	226.86611	5	45.373222	18.163*
Sprouting Time	136.51444	2	68.257222	27.324*
Type of Cereal	90.32444	2	45.16222	18.079*
Malt Concentration	0.02722	1	0.027222	0.011
2-Factor Interactions	170.44444	8	21.305556	8.529*
Sprouting Time . Type of Cereal	164.05889	4	41.014722	16.419*
Sprouting Time . Malt Conc	0.19444	2	0.097222	0.039
Type of Cereal Malt Conc	6.19111	2	3.095556	1.239
Residual	9.992222	4	2.4980556	
Total (corr)	407.30278	17		

Appendix 6 Peak viscosity

Source of Variation	SS	df	MS	F-ratio
MAIN EFFECTS	29544.444	5	5908.889	4.422*
Sprouting Time	2011.111	2	1005.556	0.753
Type of Cereal	2484.444	2	12422.222	9.267*
Malt Conc.	2688.889	1	2688.889	2.012
RESIDUAL	16033.333	12	1336.1111	
TOTAL (CORR.)	45577.778	17		

Appendix 7 Viscosity at 95°C

Source of Variation	SS	df	MS	F-ratio
MAIN EFFECTS	22972.222	5	4594.4444	3.916*
Sprouting Time	2533.333	2	1266.6667	1.080
Type of Cereal	18433.333	2	9216.6667	7.856*
Malt Level	2005.556	1	2005.5556	1.710
RESIDUAL	14077.778	12	1173.1481	
TOTAL (CORR)	37050.000	17		

Appendix 8 Viscosity at 95°C- HOLD

Source of Variation	SS	df	MS	F-ratio
MAIN EFFECTS	35794.444	5	7158.889	4.712*
Sprouting Time	8811.111	2	4405.556	2.899
Type of Cereal	25377.778	2	12688.889	8.351*
Malt Level	1605.556	1	1605.556	1.057
RESIDUAL	18233.333	12	1519.4444	
TOTAL (CORR.)	54027.778	17		

Appendix 9 Anova Summary Table for Viscosity at 50°C

Source of Variation	SS	df	MS	F-ratio
MAIN EFFECTS	550811.11	5	110162.22	28.948*
Sprouting Time	80811.11	2	40405.56	10.618*
Type of cereal	426977.78	2	213488.89	56.099*
Malt level	43022.22	1	43022.22	11.305*
2-Factor interactions	189877.78	8	23734.722	6.237*
sprout time*cerealttype	61622.22	4	15405.556	4.048
sprout time*maltlevel	35411.11	2	17705.556	4.653
cereal type*malt level	92844.44	2	46422.222	12.199*
RESIDUAL	15222.222	4	3805.5556	
TOTAL (CORR.)	755911.11	17		

Appendix 10 Anova Summary Table for Viscosity at 50°C HOLD

Source of Variation	SS	df	MS	F-ratio
MAIN EFFECTS	323005.56	5	64601.11	14.129*
Sprouting time	65100.00	2	32550.00	7.119*
Type of cereal	234433.33	2	117216.67	25.637*
Malt level	23472.22	1	23472.22	5.134
2-Factor interactions	169355.56	8	21169.44	4.630
sprout time*cereal type	91866.67	4	22966.667	5.023
sprout time*malt level	9744.44	2	4872.222	1.066
cereal type*malt level	67744.44	2	33872.222	7.408*
RESIDUAL	18288.889	4	4572.222	
TOTAL (CORR.)	510650.00	17		

ANOVA Summary Table for pH and Acidity

Appendix 11

pH

Source of Variation	SS	df	MS	F-Ratio
MAIN EFFECTS	47.146477	8	5.893310	25.201*
Fermentation Time	45.723290	3	15.24197	65.175*
Cowpea Fortification level	1.343085	4	0.335771	0.2815
Steam Treatment	0.080102	1	0.080102	0.343
2-FACTOR INTERACTIONS	4.6762025	19	0.2461159	1.052
Fermtime*Cowpea level	2.8373350	12	0.2364446	1.011
Fermtime*Steaming	1.0381075	3	0.3460358	0.2697
Cowpea level*Steaming	0.8007600	4	0.2001900	0.5171
RESIDUAL	2.8061800	12	0.2338483	
TOTAL (CORR.)	54.628860	39		

Appendix 12

Acidity

Source of Variation	SS	df	MS	F-Ratio
MAIN EFFECTS	7.1562539	8	0.8945317	71.32*
Fermentation Time	7.0495064	3	2.3498355	187.35*
Cowpea Fortification level	0.0961850	4	0.0240460	1.917
Steam Treatment	0.0105625	1	0.0105625	0.3865
2-FACTOR INTERACTIONS	0.9246981	19	0.0486683	3.880*
Fermtime*Cowpea level	0.6308206	12	0.0525684	0.430
Fermtime*Steaming	0.2723275	3	0.0907758	4.191*
Cowpea level*Steaming	0.0215500	4	0.0053875	0.7847
RESIDUAL	0.1505100	12	0.0125425	
TOTAL (CORR.)	8.2314620	39		

Appendix 13 Levels of mono-, di- and oligosaccharides determined in fermented maize/cowpea blends

cowpea level%	fermentation time/h	xylose	fructose	glu/gal	sucrose	maltose	raffinose	stachyose
5	0	0.313	0.931	11.747	0	0.600	0.156	0.139
	24	0.196	0.546	0.946	0	0.306	0	0
	48	0.392	0.709	8.926	0	0.091	0	0.029
	72	0.603	0.353	1.281	0.094	0.505	0.053	0
10	0	-	-	-	-	-	-	-
	24	0.923	1.107	11.063	0.304	0.564	0.391	0
	48	0.136	0.442	5.852	0	0.221	0	0.003
	72	-	-	-	-	-	-	-
15	0	0.381	1.080	8.066	0.173	0.649	0	0.062
	24	0.935	1.060	9.201	0.248	0.645	0.099	0
	48	0.425	0.657	5.523	0	0.270	0	0.025
	72	1.161	0.096	1.078	0.060	0.551	0.053	0
20	0	0.244	0.905	7.150	0	0.383	0	0.062
	24	0.301	0.676	9.066	0.302	0.275	0	0
	48	0.159	0.498	5.411	0	0.206	0	0.007
	72	0.646	0.070	0.959	0.020	0.639	0	0

Appendix 14 Levels of mono-, di- and oligosaccharides determined in fermented maize/ steamed cowpea blends

Steam Cowpea level%	Fermentation time/hr	XYLOSE	FRUCTOSE	GLU/GAL	SUCROSE	MALTOSE	RAFFINOSE	STACHYOSE
5	0	0.892	1.114	9.049	0	0.296	0.578	0
	24	0.476	0.601	7.241	0.036	0.299	0.060	0
	48	0.853	0	0.308	0.235	0.314	0	0.024
	72	0.504	0.179	2.717	0.094	0.784	0.023	0.177
10	0	0.597	0.922	12.728	0	0.442	0.066	0.177
	24	0.495	0.851	7.240	0.067	0.299	0.060	0
	48	0.491	0	0.276	0.140	0.275	0.161	0
	72	0.727	0.562	1.849	0	0.330	0	0.007
15	0	0.501	0.862	10.190	0.027	0.403	0.016	0
	24	-	-	-	-	-	-	-
	48	1.734	0	0.661	0.302	0.353	0	0.025
	72	0.541	0.384	2.933	0	0.249	0.002	0.111
20	0	0.717	1.073	12.204	0.040	0.244	0.016	0
	24	0.547	0.904	8.419	0.232	0.328	0.137	0.241
	48	0.658	0.055	0.646	0.104	0.334	0.684	0.056
	72	0.768	0.388	4.252	0.297	0.457	0	0.604

Appendix 15 Levels of mono-, di- and oligosaccharides determined in co-fermented maize/ cowpea blends

Cowpea level%	Fermentation time/hr	XYLOSE	FRUCTOSE	GLU/GAL	SUCROSE	MALTOSE	RAFFINOSE	STACHYOSE
5	0	0.719	0.399	4.676	0.265	0.774	0.422	0.143
	24	0.056	0.501	8.495	0	0.454	0	0
	48	0.560	0.024	0.942	0.056	0.539	0	0.016
	72	0.851	0	0.906	0.122	0.588	0.024	0.324
10	0	0.525	0.385	4.083	0.303	0.965	0.331	0.323
	24	0.485	0.771	7.967	0	0.328	0.043	0
	48	0.796	0.508	2.049	0	0.890	0.009	0.181
	72	0.521	0.481	4.370	0	0.089	0.099	0
15	0	0.489	1.079	7.683	0.224	0.586	0.920	0.160
	24	0.227	0.739	7.600	0	0.379	0.001	0
	48	0.478	0.580	4.742	0	0.489	0.140	0.018
	72	0.204	0.408	4.831	0	0.087	0	0.040
20	0	0.950	0.423	4.573	0.723	1.061	0.451	0.316
	24	0.393	0.932	8.243	0	0.188	0.011	0.136
	48	0.272	0.454	4.661	0.184	0.450	0	0.056
	72			-				

Appendix 16 Levels of mono-, di- and oligosaccharides determined in co-fermented maize/ steamed cowpea blends

Steam Cowpea level%	Fermentation time/h	XYLOSE	FRUCTOSE	GLU/GAL	SUCROSE	MALTOSE	RAFFINOSE	STACHYOSE
5	0	0.599	0.949	7.690	0.167	0.275	0.017	0.308
	24	0.823	0.923	5.133	0.105	0	0	0.584
	48	0.136	0.079	0.574	0.331	0.103	0.008	0.134
	72	0.627	0.277	3.334	0.687	0.196	0	0.056
10	0	0.517	1.036	10.727	0.105	0.513	0.031	0.350
	24	0.659	1.016	12.524	0	0.235	0.524	0
	48	0.779	0.588	0	0	0.418	0	0
	72	0.737	0	0.451	0.149	0.623	0	0
15	0	0.399	0.992	11.808	0.117	0.456	0.093	0.306
	24	0.490	0.717	7.909	0	0.301	0.036	0.026
	48	0.783	0.416	1.125	0	0.495	0.881	0.006
	72	0.350	0	2.896	0	0	0.002	0.178
20	0	0.555	0.904	10.152	0.112	0.385	0.123	0.177
	24	0.748	1.289	10.201	0	0.549	0.221	0.002
	48	0.808	0	3.615	0.286	0.495	0.881	0.006
	72	0.219	0.390	4.458	0	1.199	0	0.599

Appendix 17

Chemical composition of fermented maize/cowpea blends (% dry matter)

Fermentation Time (Days)	Unsteamed Cowpea level(%)	Ash (%)	Protein (%)	Fat (%)	Fermentation Time (Days)	Steamed Cowpea level(%)	Ash (%)	Protein (%)	Fat (%)
0	0	1.2075	8.3914	3.6755	0	0	1.2075	8.3914	3.6755
	5	1.3129	9.8486	3.2832		5	1.3214	9.1289	2.9867
	10	1.4581	-	-		10	1.3802	10.2416	3.0394
	15	1.5453	-	-		15	1.4483	10.4561	3.1734
	20	1.5402	-	-		20	1.5911	11.6464	2.8340
1	0	1.2487	8.9402	3.4471	1	0	1.2487	8.9402	3.4471
	5	1.3561	-	4.1845		5	1.2719	-	3.4056
	10	1.4368	-	3.5089		10	1.4445	-	3.2543
	15	1.4859	-	3.8062		15	1.5079	-	2.7758
	20	1.5584	-	3.5657		20	1.6183	-	2.7722
2	0	1.1688	8.5240	3.9822	2	0	1.1688	8.5240	3.9822
	5	1.3701	10.1547	-		5	-	9.9355	3.9351
	10	1.4817	11.2039	3.8145		10	1.5940	11.1104	2.9703
	15	1.5466	11.3040	3.1046		15	1.6057	11.0808	3.5749
	20	1.5400	11.4360	3.3319		20	1.7742	11.9299	3.5961
3	0	1.2916	8.9641	3.7455	3	0	1.2916	8.9641	3.7455
	5	1.3621	10.3135	3.2942		5	1.2916	10.4586	3.8094
	10	1.4747	11.4072	3.7923		10	1.4938	10.4194	3.6542
	15	1.5622	11.3999	3.0406		15	1.5343	10.4414	4.1597
	20	1.7158	12.3576	3.5182		20	1.5827	11.1812	3.8021

Chemical composition of co-fermented maize/cowpea blends (% dry matter)

Fermentation Time (Days)	Unsteamed Cowpea levels(%)	Ash (%)	Protein (%)	Fat (%)	Fermentation Time (Days)	Steamed Cowpea levels (%)	Ash (%)	Protein (%)	Fat (%)
0	0	1.2075	8.3914	3.6755	0	0	1.2075	8.3914	3.6755
	5	1.2774	9.4278	3.1417		5	1.3293	8.9486	3.5042
	10	1.3739	10.1073	2.9505		10	1.4247	-	3.4856
	15	1.4789	10.4133	2.5499		15	1.5089	10.7986	3.0034
	20	1.5798	11.6344	2.9814		20	1.6170	11.4505	2.8317
1	0	1.2487	8.9402	3.4471	1	0	1.2487	8.9402	3.4471
	5	1.3623	9.6984	3.0076		5	1.2945	9.6153	3.6050
	10	1.4285	10.4657	3.4284		10	1.3234	10.4386	3.2888
	15	1.5196	11.0861	2.8101		15	1.6167	10.5906	2.8833
	20	1.4947	11.5734	2.8672		20	1.6544	11.7751	2.6690
2	0	1.1688	8.5240	3.9822	2	0	1.1688	8.5240	3.9822
	5	1.3987	10.7508	-		5	1.4592	10.2827	3.3627
	10	1.4729	11.6403	3.6635		10	1.5586	10.9039	3.4789
	15	1.5662	10.6421	3.7885		15	1.7213	11.9695	3.8527
	20	1.6640	11.1063	3.7221		20	1.7298	12.5383	3.4718
3	0	1.2916	8.9641	3.7455	3	0	1.2916	8.9641	3.7455
	5	1.4270	10.0533	3.8883		5	-	10.1708	3.4946
	10	1.4673	8.3886	3.3681		10	1.4777	11.0548	4.0905
	15	1.5784	10.8925	3.3850		15	1.6152	11.5873	3.8581
	20	1.6662	11.7885	2.8726		20	1.6790	12.3447	3.5579

Appendix 18 Water Absorption Capacities of fermented maize/cowpea blends (% dry matter basis)

Fermentation Time (Days)	Unsteamed Cowpea Levels(%)	Water Absorption of cofermented maize/cowpea blends (%) ¹	Water Absorption of fermented maize/cowpea blends (%) ¹	Fermentation Time (days)	Steamed Cowpea Levels(%)	Water Absorption of cofermented maize/cowpea blends (%) ¹	Water Absorption of fermented maize/cowpea blends (%) ¹
0	0	114.6731	114.6731	0	0	114.6731	114.6731
	5	142.6048	136.6179		5	121.1686	129.8615
	10	-	140.0624		10	121.7534	135.8566
	15	144.9571	140.5073		15	121.8169	133.2053
	20	137.3242	146.1079		20	135.1617	140.4852
1	0	118.6975	118.6975	1	0	118.6975	118.6975
	5	124.1301	132.2226		5	115.4199	125.4236
	10	124.2137	139.5657		10	130.6627	122.1084
	15	121.8473	146.8585		15	113.3782	115.4199
	20	134.0411	133.8545		20	136.0908	133.6514
2	0	120.7402	120.7402	2	0	120.7402	120.7402
	5	127.1835	133.3353		5	136.2266	137.4582
	10	130.1206	145.6074		10	142.3521	146.7009
	15	124.2309	128.7172		15	147.8524	148.1080
	20	137.0246	143.9216		20	144.1065	152.9293
3	0	114.2845	114.2845	3	0	114.2845	114.2845
	5	122.7185	143.0052		5	148.5680	138.0563
	10	136.0395	131.9409		10	129.3342	149.2652
	15	138.8272	132.8310		15	148.3491	148.0684
	20	139.9509	144.3295		20	134.0860	153.3773

¹ - Averages of Duplicate Measurements.

Anova summary tables for mono-, di-, and oligosaccharides

Appendix 19 Xylose concentration

Source of variation	SS	df	M.S.	F-Ratio
Main Effects	0.5914295	9	0.0657144	0.887
Fermentation time	0.0025817	3	0.0008606	0.032
Fortification level	0.3117150	4	0.0779288	1.051
Steam treatment	0.2168544	1	0.2168544	0.0423
Method of fermentation	0.313533	1	0.0313533	0.423
2-Factor Interactions	1.5939728	27	0.0590360	0.797
Fermentation x Level of Time Fortification	0.7819158	12	0.0651596	0.879
Fermentation x Steam Time Treatment	0.3245593	3	0.1081864	1.460
Fermentation x Method of Time Fermentation	0.1704578	3	0.0568193	0.767
Level of Fortification x Steam Treatment	0.1132419	4	0.0283105	0.382
Level of Fortification x Method of Fermentation	0.2260110	4	0.0565027	0.762
Steam Treatment x Method of Fermentation	0.0360240	1	0.0360240	0.0486
Residual	2.8904001	39	0.0741128	
Total (corr)				

Appendix 20 Fructose concentration

Source of variation	SS	df	M.S.	F-Ratio
Main Effects	5.2752642	9	0.5861405	15.278
Fermentation time	4.9582625	3	1.6527542	43.079
Fortification level	0.3391280	4	0.0847820	2.210
Steam treatment	0.0000025	1	0.0000025	0.000
Method of fermentation	0.0261057	1	0.026157	0.680
2-Factor Interactions	2.4122705	27	0.0893595	2.329
Fermentation x Level of Time Fortification	1.2738375	12	0.1061531	2.767
Fermentation x Steam Time Treatment	0.5353396	3	0.1784465	4.651
Fermentation x Method of Time Fermentation	0.1340722	3	0.0446907	1.165
Level of Fortification x Steam Treatment	0.0558618	4	0.0139655	0.364
Level of Fortification x Method of Fermentation	0.3084440	4	0.0771110	2.010
Steam Treatment x Method of Fermentation	0.1641303	1	0.1641303	4.278
Residual	1.4962711	39	0.0383659	
Total (corr)				

Appendix 21 Glucose and Galactose concentration

Source of variation	SS	dF	MS	F-Ratio
Main Effects	657.61098	9	73.06789	18.399*
Fermentation time	583.45325	3	194.48442	48.972*
Fortification level	64.71585	4	16.17896	4.074*
Steam treatment	0.49920	1	0.49920	0.126
Method of fermentation	2.89473	1	2.89473	0.729
2-Factor Interactions	319.02549	27	11.815759	2.975*
Fermentation x Level of Time Fortification	178.53605	12	14.878004	3.746*
Fermentation x Steam Time Treatment	83.69254	3	27.897514	7.025*
Fermentation x Method of Time Fermentation	21.19755	3	7.065849	1.779
Level of Fortification x Steam Treatment	11.49094	4	2.872734	0.723
Level of Fortification x Method of Fermentation	11.54861	4	2.887152	0.727
Steam Treatment x Method of Fermentation	6.08376	1	6.083759	1.532
Residual	154.8876	39	3.9713529	
Total (corr)				

Appendix 22 Maltose concentration

Source of variation	SS	dF	MS	F-Ratio
Main Effects	0.7485572	9	0.083173	2.086*
Fermentation time	0.3113298	3	0.1037766	3.501*
Fortification level	0.2513254	4	0.0628313	2.120
Steam treatment	0.1600696	1	0.1600696	5.400*
Method of fermentation	0.0275873	1	0.0275873	0.931
2-Factor Interactions	1.4303056	27	0.0529743	1.787*
Fermentation x Level of Time Fortification	0.6520405	12	0.0543367	1.833
Fermentation x Steam Time Treatment	0.225637	3	0.0752179	2.538
Fermentation x Method of Time Fermentation	0.337039	3	0.112346	3.753*
Level of Fortification x Steam Treatment	0.0514112	4	0.0128528	0.434
Level of Fortification x Method of Fermentation	0.0805966	4	0.0201491	0.680
Steam Treatment x Method of Fermentation	0.0564429	1	0.0564429	1.904
Residual	1.1560114	39	0.0296413	
Total (corr)				

Appendix 23 Sucrose concentration

Source of variation	SS	df	MS	F-Ratio
Main Effects	0.1461420	9	0.0162380	0.958
Fermentation time	0.0255815	3	0.0085272	0.503
Fortification level	0.1057392	4	0.0264348	1.560
Steam treatment	0.0012271	1	0.0012271	0.072
Method of fermentation	0.0121874	1	0.0121874	0.719
2-Factor Interactions	0.7726717	27	0.0286175	1.689
Fermentation x Level of Time Fortification	0.2894190	13	0.0241183	1.423
Fermentation x Steam Time Treatment	0.1867422	3	0.0622474	3.674
Fermentation x Method of Time Fermentation	0.1887156	3	0.0629052	3.713
Level of Fortification x Steam Treatment	0.014831	4	0.0026208	0.155
Level of Fortification x Method of Fermentation	0.1020402	4	0.0255100	1.506
Steam Treatment x Method of Fermentation	0.0012471	1	0.0012471	0.074
Residual	0.6608184	39	0.0169441	
Total (corr)				

Appendix 24 Raffinose concentration

Source of variation	SS	df	MS	F-Ratio
Main Effects	0.5530883	9	0.1058987	2.672
Fermentation time	0.6112358	3	0.2037453	5.142
Fortification level	0.2482588	4	0.0620647	1.566
Steam treatment	0.194740	1	0.194740	0.491
Method of fermentation	0.0803002	1	0.0803002	2.026
2-Factor Interactions	1.3840029	27	0.0541724	1.367
Fermentation x Level of Time Fortification	0.6500692	12	0.0541724	1.367
Fermentation x Steam Time Treatment	0.3877878	3	0.1292626	3.262
Fermentation x Method of Time Fermentation	0.0954391	3	0.0318130	0.803
Level of Fortification x Steam Treatment	0.1671551	4	0.0417888	1.055
Level of Fortification x Method of Fermentation	0.0681994	4	0.0170499	0.430
Steam Treatment x Method of Fermentation	0.0068087	1	0.0068087	0.172
Residual	1.5454332	39	0.0396265	
Total (corr)			407.30278	17

Appendix 25 Stachyose concentration

Source of variation	SS	df	MS	F-Ratio
Main Effects	1.7131438	9	0.1903493	12.832*
Fermentation time	0.9065902	3	0.3021967	20.372*
Fortification level	0.6202431	4	0.1550608	10.453*
Steam treatment	0.0223155	1	0.0223155	1.504
Method of fermentation	0.0755554	1	0.0755554	5.093
2-Factor Interactions	1.8763592	27	0.0694948	4.685*
Fermentation x Level of Time Fortification	1.6717886	12	0.0694948	4.685*
Fermentation x Steam Time Treatment	0.0576387	3	0.019212	1.295
Fermentation x Method of Time Fermentation	0.0520636	3	0.0173545	1.170
Level of Fortification x Steam Treatment	0.0426785	4	0.0106696	0.719
Level of Fortification x Method of Fermentation	0.0051440	4	0.0012860	0.087
Steam Treatment x Method of Fermentation	0.0002518	1	0.0002518	0.017
Residual	0.5785274	39	0.0148340	
Total (corr)				

Appendix 26

Coefficients of variables and their contribution to R²

Variable	10rpm	R ²	20rpm	R ²	50rpm	R ²
X ₁	-2.5018	0.1898	-		-57.189164	0.00002947
X ₂						
X ₃					0.004312*	0.9249
X ₁ ²					0.704201*	0.001567
X ₂ ²	2.1703*	0.5454	-16.9329	0.5454		
X ₃ ²						
X ₁ X ₂						
X ₁ X ₃	4.2062E-6*	0.2180	0.000026*	0.4035	0.000191*	0.04606
X ₂ X ₃	-		-0.000035	0.004568	0.000808	0.01068
R ²		0.9532		0.9535		0.9832
X ₁	temperature	X ₂	concentration	X ₃	Brookfield viscosity	
* - significant at p ≤ 0.05						