EVALUATION OF KOMI PROCESSING - PROCESS AND PRODUCT CHARACTERISTICS

by

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DEDICATION

Dedicated to Mama

For God is able to do very much more above

all that we ASK or IMAGINE

according to the POWER that is at WORK in US...

Eph 3:20

ABSTRACT

A sociological and techno-economic survey of *komi* processing was carried out in the Accra-Tema metropolis. The results indicated that the *Komi* industry is essentially controlled by women in their prime of life having very little or no formal education. Men play a supportive role. Production is on small-scale and profit margin generally increases with increase in quantity of maize used per batch of *komi*. The industry is heavily dependent on household hands and locally fabricated and manufactured equipment. *Komi* processing is based on traditional technology. Unit operations identified as critical for the achievement of good quality *Komi* are: cleaning of maize, steeping, milling, moisture content of dough, fermentation, preparation of glutinous paste, preparation of *Aflata*, packaging and boiling. These operations contribute to the development of desirable chemical, physical and organoleptic characteristics of product. They also contribute to increase in bulk of the product.

Results from experiments on soaking time, soaking temperature, initial moisture and fermentation time on physicochemical properties of maize dough (an intermediate product for making *Komi*) have shown that development of dough sourness (acid production) is essentially due to fermentation. The observed effects of fermentation on dough acidity is dependent on pre-fermentation treatment conditions such as soaking time, soaking temperature and

initial moisture contents of the dough system. Increasing soaking temperature (in the range of 45°C to 60°C) and initial moisture (in the range of 45% to 55%) favours high dough acidity. Dry-milling of maize leads to high acid production during fermentation. Cooked paste characteristics (as measured by Brabender viscoamylograph and Brookfield viscometer) were affected by soaking time, soaking temperature and fermentation time. Viscosity increases with fermentation time. Dry-milling of maize results in low cooked paste viscosity of dough during fermentation.

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1.0 INTRODUCTION

1.1 Importance of Cereal Foods In Ghanaian Diet

Cereals are important staples in the diet and nutrition of the people of West Africa. In Ghana the survival, security and performance of the individual and households are heavily dependent on cereal foods. They provide the bulk of the energy requirements of the population and make significant contribution to food proteins, lipids, some vitamins and minerals (Sefa-Dedeh and Mensah, 1988). The chemical composition of cereals common in Ghana is shown in Table 1.

Table 1 Chemical Composition of Cereals

	Cereal (g/100g edible portion)			
	Maize	Rice	Sorghum	Millet
Moisture	12.0	12.0	9.9	8.4
Protein	9.5[1]	7.2[2]	9.9[1]	8.6[1]
Fat	4.0	0.4	3.1	4.0
Fibre	1.4	0.3	1.4	1.2
Ash	1.3	0.5	1.4	1.6
Mineral (mg/100g)				
Iron	4.5	2.2	8.5	3.8
Calcium	10.0	8.0	14.0	20.0
Phosphorus	218.0	160.0	300.0	312.0

1 = N x 6.25 **2 = N x 5.95**

Source: Watson (1971)

Four main cereals are grown in Ghana. These are: maize (Zea mays), sorghum (*Sorghum bicolor*), millet (*Pennisetum typhoides*) and rice (*Oryza sativa*). Maize is the most important of the cereals (grown in Ghana) in terms of utilization, acreage cultivation and production level.

1.2 Cereal Foods in Ghana

A wide variety of traditional cereal foods are available for consumption in Ghana. In a recent survey it was found that over 50 different products can be made from maize alone (Sefa-Dedeh, 1992). These foods can be categorised into six main groups:

i. Dumplings: which comprises the kenkeys (Fanti, *Komi, Osino, Estew*) and others such as *Fula* and *Fonfom*;

ii. Beverages (alcoholic and non-alcoholic): such as *Pito, Nmeda, Tuei, Solom* and *Asaana*;

iii. Porridges: such as *Koko, Ekoegbemi, Peewa, Oblayo*;

iv. Baked products: such as *Aboloo, Bodoo*;

v. Fried products: such as *Maasa, Banfobese*;

vi. Roasted products: such as *Lakoa*.

Not only are these food products in high demand, but are also produced in homes and small-scale cottage industries in the cities, towns and villages at prices easily affordable to consumers.

1.3 Cereal Processing in Ghana

The traditional food processing technologies are the means for the transformation of cereals into the various food products. They serve as the vehicle for national food delivery and nutrition, and provide employment and income to technology users (Sefa-Dedeh, 1989).

Some characteristics of traditional food processing technologies are:

a. operation on small-scale or subsistence level,
b. uses simple equipment and implements,
c. processes are labour-intensive, uncontrolled, unstandardised and inefficient,
d. dominated by women, majority of them illiterates (Sefa-Dedeh, 1989),
e. ecologically friendly.

1.3.1 The State of Traditional Cereal Processing Technologies

Development of traditional cereal processing technologies is still in the rudimentary stages. The scientific basis of the processes are not fully understood, also there are inherent inefficiencies in the unit operations and deficiencies in the end product quality. Opportunities exist for research in the following areas:

a. product shelf stability studies,
b. reduction of the long time for processing,
c. improvement of the laborious unit operations,
d. package studies,
e. product convenience (Sefa-Dedeh,1992),
f. social and economic factors relating to processing.

1.4 Cereal Processing - Case Study of *Komi*

Komi is a fermented cereal-base dumpling widely eaten in the Greater Accra region of Ghana, and in other parts of the country (Bediako-Amoa 1973, Sefa-Dedeh & Plange 1989).

It is prepared from maize (*Zea mays*) and packaged in maize sheath using traditional technology.

1.4.1 Processing of *Komi*

The basic unit operations in *komi* processing are: cleaning of maize, steeping, milling, dough preparation, cooking, *aflata* preparation, packaging and boiling (Ofosu 1967, Bediako-Amoa 1973, Sefa-Dedeh & Plange 1989). Almost all these processes are critical for achieving good quality *komi* (Bediako-Amoa & Austin 1976, Sefa-Dedeh & Plange, 1989).

The maize is cleaned, soaked in water for 18 to 72 hours and milled into meal. The meal is made into dough by mixing with sufficient quantity of water and allowed to undergo spontaneous solid-state fermentation (fermentation involving dough containing limited amount of water) for 1 to 4 days. Part of the fermented dough is slurried, cooked into glutinous paste and mixed with raw fermented dough to form *aflata*. *Aflata* of desired size is packaged in maize sheath and boiled for 1 to 4 hours to obtain *komi* (Ofosu 1967, Bediako-Amoa 1973, Sefa-Dedeh & Plange 1989).

1.4.2 Process and Product Characteristics of *Komi*

The process and product characteristics of *komi* have been enumerated as:

i. the long processing time associated mainly with soaking and fermentation (Ofosu 1967, Sefa-Dedeh & Plange 1989);

ii. the drudgery associated with cooking of the glutinous paste and preparation of *aflata* (Ofosu 1967, Bediako-Amoa 1973, Owusu-Ansah *et al.*, 1980, Sefa-Dedeh & Plange 1989);

iii. unstandardized method of preparing the dough leading to wide variations in dough quality (Plahar & Leung 1982);

iv. short shelf-life of maize dough and product (Plahar & Leung 1985, Sefa-Dedeh & Plange 1989).

The key to improvement in the process and product characteristics rest on the full evaluation and complete understanding of the microbiological, physicochemical and organoleptic changes that occur in the system at each process, the agents which effect the changes and the substrate and process conditions which will guarantee optimization of the desired quality attributes.

1.5 Objectives

1.5.1 Survey

1. To study the social characteristics of *komi* processors,
2. To collate information on processing methods of *komi*, product shelf-life and storage conditions;
3. To cost analyse and assess the profitability of *komi* processing,
4. To find out which aspect of traditional *komi* processing has undergone changes,

5. To determine the variety of maize preferred in the making of *komi* and the factors that determine the choice of maize.
6. To investigate other socio-economic factors relating to *komi* processing such as identification of marketing policies and strategies pursued in the sale of product;

1.5.2 Laboratory Studies

To establish the scientific basis of some unit operations in the *komi* process:

i. evaluation of uptake of water in whole and cracked maize during steeping;

ii. investigation of the effects of soaking of maize, initial moisture content of dough and solid-state fermentation on the physicochemical properties of dough systems;

iii. to determine the optimum conditions of soaking, initial moisture of dough and fermentation that yields maximum desirable attributes of product.

2.0 LITERATURE REVIEW

2.1 Maize

2.1.1 History

Maize (*Zea mays*) is believed to have been first domesticated in Central Mexico by human selection from mutants of grass, teosinte (*Zea mays* ssp. Mexicana) [Beadle, 1978]. The teosinte origin has been buttressed by the discovery of a wild perennial teosinte, *Zea diploperemis* Iltis (Iltis *et al*., 1979) which has the same number of chromosomes as maize. Maize was introduced into Europe by Columbus at the end of the 15th century (Matz, 1969) from where it spread to other parts of the world.

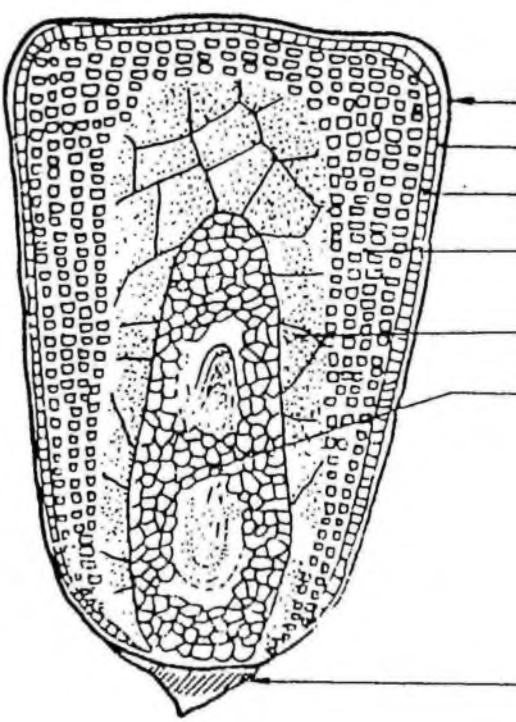
2.1.2 Structure and Chemical Composition

The mature maize grain is composed of roughly four parts: (1) tip cap, 1.46% (2) pericarp, 5.93% (3) germ, 11.53% (4)endosperm, 81.08% (Shukla, 1981), (Figure 1).

The tip cap is composed of insoluble fibrous material well adapted for rapid water absorption (Wolf *et al*., 1952).

The pericarp is a dense material which covers the outside of the kernel (Wolf *et al*., 1952). It comprises of 3 layers - the outer, middle and inner layers. The outer layer is made of a wax-like cutin and resists water entry. The middle layer comprising of the spongy tube cell and cell layer permit easy uptake of water. The inner layer is a suberized thin layer called the seed coat. It acts as a semi-permeable membrane.

Fig 1 Longitudinal Section of the Maize kernel: Morphology and Composition (Shukla, 1981).



	% OF WHOLE KERNEL	% FAT
PERICARP	5.93	0.89
TESTA		
ALEURONE	7.12	6.99
HORNY ENDOSPERM	51.00	0.47
SOFT ENDOSPERM	22.96	
GERM	11.53	34.84
CAP	1 46	1.46
WHOLE KERNEL		4.76

The germ contains about 34.8% oil and 18.8% protein (Shukla, 1981) and is rich in vitamins and minerals. It consists of two major parts: the scutellum and embryonic axis. The latter is the structure that grows into seedling (Wolf *et al.*, 1952), whilst the former serves as a storage organ from which nutrients and enzymes are mobilised to provide nourishment for the embryo (Dure, 1963).

The endosperm which forms the bulk of the kernel has two parts, the floury endosperm close to the germ and the horny endosperm. The endosperm has a cellular structure and each cell is filled with starch granules. The cells of the floury region are round or oval in shape, with interstitial spaces in-between cells. These cells are loosely filled with spherical starch granules. In contrast the cells of the horny layer are more angular and compact without interstitial spaces between cells, and are filled with densely packed polygonal starch granules (Raju *et al.*, 1991).

Depending on the proportion of floury to horny portion, the varieties of maize are classified as: dent, flint, floury and pop corn (Leonard & Martin 1963, Kent 1983). Dent corn has a ratio of about 1:2 floury to horny regions but varies depending on the protein content of the grain (Wolf *et al.*, 1952), flint and pop corn contain very little core of floury region surrounded by a horny region which resists denting when the grain is dried, and floury maize essentially comprises of floury region.

Varietal differences in maize is of importance to the user since they can affect the performance of the meal or flour in food products.

2.1.3 Production Level & Varieties in Ghana

Maize is the most important cereal crop in terms of acreage cultivation, production level and use in Ghana (Tables 2 & 3). Dent maize is the most popular in Ghana. There are many improved varieties in addition to the Local variety (Table 4).

Table 2 Production Estimates for Cereal Crops in Ghana: 1983 - 1991 (Figures in `000 Metric Tonnes)

Crops	1983	1984	1985	1986	1987	1988	1989	1990	1991
Maize	140.8	574.0	395.0	559.1	597.7	600.0	715.0	523.0	931.5
Rice	26.9	76.0	80.0	69.6	80.7	105.0	67.0	81.0	105.9
Sorghum	105.8	176.0	185.0	128.1	205.9	177.6	213.0	136.0	241.4
Millet	114.4	139.0	120.0	109.9	173.1	192.4	180.0	75.0	112.4

Source: Policy Planning, Monitoring and Evaluation (PPME) Ministry of Agriculture (1992).

Table 3 Area Estimates of Cereal Crops in Ghana: 1983 - 1991 (Figures in `000 HA)

Crop	1983	1984	1985	1986	1987	1988	1989	1990	1991
Maize	279.8	723.6	405.0	472.1	548.3	500.0	595.8	464.8	610.0
Rice	38.6	68.8	87.0	76.1	72.0	116.6	74.4	88.3	94.9
Millet	213.7	231.0	222.0	156.6	235.0	228.2	244.0	123.7	208.5
Sorghum	213.6	251.0	250.0	176.4	271.6	243.0	295.5	243.0	262.6

Source: PPME Ministry of Agriculture (1992)

Table 4 Proximate Composition of some Maize Varieties Grown in Ghana

Variety	Moisture Content	Percent Ash	Crude Protein	Crude Fibre	Crude Fat
Aburotia	10.78	1.15	9.49	5.70	7.38
Composite W	15.06	0.88	9.41	2.31	3.06
Diamantes	14.16	0.54	8.45	2.48	5.21
Dobidi	12.31	0.84	10.12	2.17	5.93
Dorke	10.53	1.47	9.77	2.63	5.05
Golden Crystal	11.67	1.09	12.91	2.80	4.42
Hilysine	12.36	1.29	11.80	2.70	5.88
La Posta	11.63	1.04	13.00	2.78	5.88
Local	10.42	1.19	10.87	2.30	2.66
Mexican	14.43	0.94	8.48	2.72	4.07
Pool 16	11.01	1.12	10.47	2.88	7.94
Safita	11.42	1.08	10.44	2.20	5.13
TZE SRW	11.14	0.99	11.28	2.63	6.19
Obatanpa*	-	-	-	-	-
Okomasa*	-	-	-	-	-

Source: Sefa-Dedeh, S. 1988.

* From Ghana Grains Development Project 1992.

2.2 Traditional Maize Processing Methods

The traditional technology for processing maize in Ghana can be classified into two: dry-milling and wet-milling. The basic operations in the dry-milling processing may involve roasting, milling and cooking. Under the wet-milling processing technologies two different basic operations exist in the manufacture of beverages and other foods. The unit operations in beverage manufacture are: steeping, sprouting, drying, milling, boiling and fermenta-tion (Sefa-Dedeh & Asante 1988, Sefa-Dedeh & Mensah 1988). Wet-milling processing for other foods may involve soaking, milling, cooking and texturization.

2.3 *Komi* Processing

The *komi* industry is a home-based enterprise which contributes towards feeding and generation of income for the family (Sefa-Dedeh & Plange, 1989). Essentially it is operated on commercial basis on small-scale (2.5 to 25 kg of maize). Financial constraints which stems from lack of available credit schemes from the banks has been mentioned as the primary cause for the size of operation (Sefa-Dedeh & Plange, 1989). The industry is controlled by women whose ages range from 19 to 48 years. Men are engaged in only the milling operation where their essential services are paid for (Sefa-Dedeh & Plange, 1989). The level of education of *komi* processors is generally low. Seventy percent of them do not have any formal education (Sefa-Dedeh & Plange, 1989).

2.3.1 Raw Material

Maize (*Zea mays*) is the predominant raw material used for the manufacture of *komi*. The other raw materials used are salt and maize sheath (Ofosu 1967, Bediako-Amoa 1973, Sefa-Dedeh & Plange, 1989).

Maize is purchased with cash (83.3%), on credit (8.3%), or a combination of the two (8.3%) from the various marketing centres in Accra or from Asasewa in the Eastern region of Ghana (Sefa-Dedeh & Plange, 1989).

In the manufacture of *komi*, processors are very particular about the variety of maize used (Sefa-Dedeh & Plange, 1989). Varietal differences in terms of morphology, structure and composition can affect the quality and yield of the product (Sefa-Dedeh, 1988). In a recent survey Sefa-Dedeh and Plange (1989) reported of some complaints from *komi* processors against the poor performance of meal of the improved varieties of maize in *komi*. These undesirable varietal characteristics include: chaffiness, poor cooked paste texture and flavour, and poor swelling on soaking.

2.3.2 Desirable Characteristics of *Komi*

The quality characteristics of *komi* are very important and is the primary determinant of product sales. Although they (quality characteristics) vary depending on the locality, there are generally accepted quality characteristics which include:

i. a uniform and very pale yellow to creamy white colour, which automatically disqualifies the use of pigmented varieties such as yellow and red maize;

ii. a well balanced, slightly acidic taste, which is neither salty nor sweet;

iii. a typical maize and mild alcoholic odour, and

iv. a moist, soft and smooth product devoid of all traces of hardness and toughness (Bediako-Amoa, 1973).

2.4 Process and Product Evaluation

2.4.1 Steeping of Maize

The steeping operation is a critical step in wet-milling of maize. It contributes to the quality of the meal and the product. The process results in imbibition of water with concomitant swelling and softening of the kernels; incubation of desirable microorganisms; initiation of fermentation; and improvement in sensory and rheological properties of the meal or dough and product.

In the manufacture of *komi* steeping is important for the softening of the maize, and improvement in taste, flavour and texture (Nyarko-Mensah 1972, Sefa-Dedeh and Plange 1989).

2.4.1.1 Physicochemical Changes Associated with Steeping of Maize

There is rapid uptake of water by maize kernel at the initial stages of the steeping process via the tip cap and pericarp. This is followed by a slow process associated with the uptake of water by the endosperm through the testa (Wolf *et. al.*, 1952a, Akinrele 1970, Oguntunde & Adebawo 1989).

In the traditional processing of *komi* the grain is normally soaked for 18 to 48 hours except in varieties with chaffy characteristics which do not soften easily and therefore steeped for 48 to 72 hours (Sefa-Dedeh & Plange, 1989). Wagoner (1948) in studies on the industrial steeping of maize reported that the grains become softened and the desirable microorganisms for initiation of fermentation are incubated in the initial 24 hours of the process. According to Akinrele (1970) most of the absorption of moisture by the kernel and the bulk of the swelling of the grain occurs during the first 24 hours of steeping. Further steeping results only in the depletion of limited supply of fermentable carbohydrates of maize. Bond and Glass (1963) in studies on steeping of maize identified sucrose as the predominant sugar lost during steeping through leaching.

Various workers have investigated the possibility of reducing the steeping time of cereals by increasing the rate of water uptake by the kernel. Oguntunde and Adebawo (1989) in studies on uptake of water by cereal (varieties of maize, sorghum and millet) grain at soaking temperatures of 30 to 45°C reported that water uptake by the kernel increased with increase in temperature of soak water; that peak water uptake occurred at about 36 hours, irrespective of the soaking temperature used; and that peak moisture content (% wet basis) however increased with increasing temperature.

Small natural population of bacteria, yeasts and mould are found on maize grains and these are capable of rapid multiplication in aqueous systems (Watson, 1984). Lactic acid bacteria present proliferates and produces lactic acid and other acids which lower the pH of the aqueous medium, thereby suppressing the activity and growth of other microorganisms and also contributes to softening of the kernel. Substrate for microorganisms are soluble sugars and amino acids which leach out of the maize kernel during steeping (Watson, 1984).

The characteristics of macromolecules present in the kernel can be altered by the treatment of steeping. Gough and Pybus (1971) soaked undamaged wheat starch granules at 50°C for 72 hours and discovered that the gelatinization temperature increased and occurred more suddenly. This phenomenon was attributed to a modification of the internal structure (annealing) of the granules. Anim (1991) in studies on soaking of maize at 30, 50 and 70°C for 24 hours reported that the gelatinization temperature increased with increase in soaking temperature.

Vivas *et al*., (1987) evaluated the effect of steeping on maize and sorghum for the preparation of "Atole". They reported that the process yielded finer particle size and less damaged starch of meal, and improved on the Brabender cooked paste viscosity.

2.4.2 Milling

Milling is a very important unit operation in cereal processing. In Ghana almost all the cereal commodities undergo some form of particle size reduction as a first step towards utilization (Sefa-Dedeh & Mensah, 1988).

The reasons for size reduction are varied. Brennen *et al.*, (1969) enumerated some of the reasons for size reduction as:

i. size reduction may aid the extraction of a desired constituent from a composite structure;

ii. reduction to a definite size range may be a specific product requirement;

iii. decrease in particle size of material leads to an increase in surface area of the solid;

iv. intimate mixing and blending is usually easier with smaller size ranges of particles.

In the manufacture of *komi* size reduction is done because:

i. it increases the surface area of the maize grains thereby facilitating processes such as mixing, fermentation and cooking;

ii. it helps to develop desired sensory qualities such as taste, colour and texture (Sefa-Dedeh & Plange, 1989).

The disc attrition mill (commonly called "cornmill") has essentially replaced the traditional grindstone, mortar and pestle as the equipment for size reduction. Tradition-ally milling is the work of women (Osei-Opare, 1989), these were in the days when the process was accomplished by means of grindstone, mortar and pestle. With the introduction of the disc attrition mill into the *komi* industry however, the milling operation has been taken over by men (Sefa-Dedeh & Plange, 1989). The reason being that the operation of the mill requires skill and strength, and women (in Ghana) feel "intimidated" in both areas (Osei-Opare, 1989).

The disc attrition mills are owned by businessmen who operate them on commercial basis (Sefa-Dedeh and Plange, 1989). It has been suggested (Osei-Opare, 1989) that ownership and operation of these mills be in the hands of women processors for cost effective running of the traditional food industries. This suggestion does not seem practicable at least in the foreseeable future because of the high cost of the equipment which is above the means of women in the traditional food processing industries and the fact that it is now accepted that the operation of these equipment is the work of men. In *komi* processing the grains are wet-milled whole into meal. The presence of the germ tends to improve the flavour and nutritional quality of the product (Ofosu 1967, Sefa-Dedeh & Plange 1989).

The performance of the disc attrition mill in terms of efficiency of milling, is not uniform, yielding a product of different particle sizes (Sefa-Dedeh, 1989). The factors which tend to affect the milling efficiency have been identified as the physical and chemical properties as well as the structure and morphology of the grain (Manoharkumer *et al.*, 1978, Pomeranz *et al.*, 1986, Vivas *et al.*, 1987). Small size and soft texture kernels are more amenable to milling than large size and hard texture kernels (Vivas *et al.*, 1987). The variations in particle size tend to affect performance of meal or flour in various food products in terms of texture, functional and rheological properties (Badi *et al.*, 1977, Vivas *et al.*, 1987, Sefa-Dedeh 1989, Budu 1990).

During milling of cereals some starch granules become damaged. The level of damaged starch can be influenced by the texture of the endosperm and the fineness of the flour or meal (Bediako-Amoa & Austin 1976, Nishita & Bean 1982, Kent 1983, Vivas *et al.*, 1987). In general hard texture endosperm is more susceptible to starch damage than the soft texture kernels. Meal or flour with relatively fine particle size is more likely to have higher damaged starch content. Damaged starch tends to affect the performance of meal or flour in food products. Ponte *et al.*, (1961) and Kent (1983) reported that high proportion of damaged starch increased gassing power and water absorption, reduced the tolerance of mixing and generally was deleterious to bread quality. Vivas *et al.*, (1987) showed that high damaged starch content of meal yields low Brabender cooked paste viscosity. In certain situations high damaged starch is essential for the development of desirable quality attributes. In studies on *aflata* process Bediako-Amoa & Austin (1976) reported that high starch damage resulting from the stirring and kneading of the glutinous paste was essential for the texture development of *komi*. Simulation of the process by causing high starch damage of meal using the hammer mill failed to achieve the desired texture of *komi*.

2.4.3 Preparation of Maize Dough

In a survey, Plahar and Osei-Yaw (1978) reported wide variations in moisture content of maize dough sold on the Ghana market. Plahar and Leung (1982) showed that variation in the initial moisture content of dough had significant effect on the chemical changes which occurred during fermentation, and used it to predict its consumer acceptability using volatile:non-volatile acids ratio suggested by Banigo and Muller (1972). Using four dough samples of varying moisture content:

45%, 52%, 65% and 80%, Plahar and Leung (1982) reported that the desired volatile to non-volatile acids ratio of 0.16 and titratable acidity of 2.4 mg NaOH g^{-1} sample could be achieved with only the 52% moisture samples.

2.4.4 Fermentation

2.4.4.1 Reasons for Fermentation

Fermentation of food has been practised in almost all human cultures for various reasons. They include:

a. improvement in nutritional value: often times fermentation leads to upgrading of the protein and vitamin contents of the product,

b. preservation of food products: some food commodities such as fish, cereals, meat, vegetables and milk can be preserved by lactic acid produced during fermentation,

c. improvement of organoleptic and rheological properties: fermentation causes improvement in texture, consistency, appearance, flavour, taste of the food and may shorten cooking time of the product,

d. improvement of digestibility and detoxification: antinutritive factors inherent in food commodities as well as enzyme-substrate produced toxic materials are destroyed during fermentation,

e. production of intoxicant delights such as alcoholic beverages and gins (Steinkraus, 1982).

2.4.4.2 Classification of Indigenous Food Fermentation

Steinkraus (1985) classified indigenous food fermentation as follows:

a. fermentations involving proteolysis of vegetable proteins by microbial enzymes in the presence of salt or/and acid with production of amino acids and peptide mixtures with a meat-like flavour (eg. soy sauce, miso and Indonesian 'kecap'),

b. fermentation in which fish and shrimp or other marine animals undergo enzymatic hydrolysis in the presence of relatively high salt solutions to produce meat flavoured sauces and pastes,

c. fermentations where cereal-grain-legume is transformed into meat-like texture by means of fungal mycelium (eg. Indonesian and Malaysian 'tempe kedela', Indonesian 'oncom kecang'),

d. fermentation involving the growing of microorganism with desired enzymes on cereal-grain legume or cassava to produce an `inoculum' (eg. koji, Kudeme) which is a crude enzyme concentrate and is used to hydrolyse particular components in the desired fermentation,

e. fermentation which produces organic acids as the major products (eg. African `ogi', sauerkraut, cheeses),

f. fermentation in which ethanol is a/the major product (eg. sugar-cane wines, beers).

2.4.4.3 Agents of Fermentation

The primary agents of food fermentations are microorganisms. According to Vanveen (1957), foods are fermented insofar as at least one of their components has undergone significant change(s) due to the enzyme action of bacteria, fungi or/and yeast. Although enzyme-induced chemical changes in the food material can be attributed partially or wholly to enzymes indigenous to the food material, a good fermentation is one in which the fermentative microorganisms play the primary role.

2.4.4.4 Fermentation of Maize Dough

Fermentation of maize dough for the manufacture of *komi* is an organic acid fermentation. The duration of the process is 24 to 96 hours (Ofosu 1967, Bediako-Amoa 1973, Plahar & Leung 1982, Sefa-Dedeh & Plange 1989). During this period a series of complex reactions involving basically carbohydrates, proteins and fats are triggered off and sustained by microorganisms leading to the development of desired physicochemical and organoleptic qualities (Sefa-Dedeh & Plange, 1989).

Chemical Changes

In a recent survey Sefa-Dedeh and Plange (1989) reported that the primary objective for traditional fermentation of maize dough in Ghana is to cause souring of the dough with its associated improvement in taste, flavour and texture.

Souring has been attributed mainly to the production of organic acids and alcohols by fermentative lactic acid bacteria and yeasts (Christian 1966, Akinrele 1970, Banigo & Muller 1972, Plahar & Leung 1982). The major carboxylic acids produced during fermentation of maize dough were identified as lactic acid, acetic acid, butyric acid and propionic acid (Plahar & Leung, 1982). The amount of acid produced during fermentation is dependent on various factors. In studies on fermentation of slurry of meal (liquid-state fermentation) for ogi preparation Akinrele (1970) reported that a relatively greater quantity of organic acid was produced from dry-milled maize compared to wet-milled maize. Plahar and Leung (1982) reported that the amount of acids produced during fermentation of maize dough depended on the initial moisture content, and that the high rate of development of carboxylic acids was associated with relatively high initial moisture content of dough.

Dough Stability and Safety

Some degree of safety and storage stability is imparted to maize dough during fermentation. Mensah *et al.*, (1990) investigated the microbiological quality involving 51 samples each of fermented and unfermented maize dough. The log Gram-negative bacteria counts averaged 5.9 and 4.0 for fermented and unfermented dough respectively. All the unfermented dough samples contained Gram-negative bacteria as compared to only 16 of fermented samples. Nine unfermented dough samples contained *Escherichia coli* carrying plasmids bearing genes for enterotoxins but non was found in the fermented dough system. Recently Mensah *et al.*, (1991) simulated the unhygienic conditions typical of some rural communities by inoculation of maize dough with *Shigella flexneri* and enterotoxigenic *Escherichia coli* (ETEC). The unfermented dough did not inhibit any of the strains. However half of the strains inoculated into the dough after fermentation had become established were inhibited 8 hours later. Consequently they suggested that the antimicrobial property of fermented dough is not due to decrease in pH of the system per se, but rather the presence of antimicrobial agent(s) produced during fermentation.

Although fermentation imparts some degree of shelf stability to maize dough, its shelf life is still very short, 4 to 5 days (Bediako-Amoa, 1973). Utilization of the dough commences after 24 hours of fermentation and continues until it is used up usually within 3 to 4 days. During this period fermentation continues. Bediako-Amoa (1973) reported that best *komi* is obtained from dough which has fermented for 48 hours, and that further fermentation only adversely affects consumer acceptance. This has been attributed to predisposition of dough to secondary fermentation with increases in fermentation time (Banigo & Muller, 1972). To curb further fermentation and achieve better shelf-stability of maize dough, Plahar and Leung (1983) dehydrated maize dough using laboratory cabinet drier at 61°C. Organoleptic tests conducted on the dry meal were less preferred by consumers compared to freshly fermented dough. This was attributed to further fermentation of the dough during drying and concomitant loss of up to 20% of the volatile acids. Sefa-Dedeh and Plange (1989) suggested that ways must be identified to stop the fermentation process and preserve the dough in a form that can keep for a long period without change in quality of the dough.

Rheological Changes

Effect of fermentation on cooked paste characteristics of maize has been investigated. Anim (1991) studied the effect of fermentation on dough prepared from maize steeped at 30°C, 50°C and 70°C for 24 hours. The gelatinization temperature of the dough samples tended to increase with increase in fermentation time and steep temperature. Osa-Mensah (1991) in studies on solid-state fermentation of dough prepared from dry-milled and wet-milled cereal (maize, sorghum and millet) reported that fermentation tends to increase the gelatinization temperature of dough, and that the increase was relatively high in dough samples prepared from dry-milled cereal.

In general, solid-state fermentation of maize dough fall into two categories - single-component and multi-component fermentation. In single-component fermentation maize alone is used whilst multi-component fermentation involves the use of maize and admixtures. Common admixture used in multi-component maize dough fermentation include: spices (pepper, ginger, clove), soy flour and lime. The physical changes which occur in the dough during the fermentation process depends on whether it is single- or multi-component system. In studies to determine the effects of some admixtures on cooked paste characteristics of maize dough, Ampadu (1991) reported that soy flour reduced the degree of increase in viscosity associated with solid-state fermentation of maize dough. Sefa-Dedeh (1991) reported that when maize dough containing lime [$Ca(OH)_2$] is fermented, there is reduction in the amylographic viscosity of the cooked dough.

Findings on the effect of fermentation on Brabender cooked paste viscosity of single-component maize dough seem to be contradictory. Ofosu (1967) and

Sefa-Dedeh (1989) reported that Brabender cooked paste viscosity of maize dough tends to decrease with increase in fermentation time. This finding is contrary to what has been reported by Ampadu (1991), Anim (1991), Anti-Donkor (1991), Osa-Mensah (1991) and Mensah *et al.*, (1990), that solid-state fermentation leads to increase in cooked paste viscosity of maize dough. Also, studies on solid-state fermentation of sorghum (Westby and Gallat, 1991) and millet (Osa-Mensah, 1991) showed increase in cooked paste viscosity of dough with increase in fermentation time. Furthermore, Banigo, De Man and Duitschaeuer (1974) in studies on liquid-state fermentation of maize slurry for the preparation of `ogi' reported that cooked paste viscosity (of the maize slurry) increases when fermentation time is increased.

2.4.5 **Cooking of Starchy Foods**

The cooked paste viscosity characteristics of maize dough is a very important quality attribute in the manufacture of *komi*. At various stages of processing the dough (or slurry of dough) undergoes heating, cooking and other processing operations which tends to change the viscosity characteristics of the product. Starch present in the system is primarily responsible for these changes.

2.4.5.1 Starch Structure

Starch occurs as a dense, quasi-crystalline, water-insoluble granule with an ordered internal structure (Banks & Greenwood 1975, Galliard & Bowler 1984, French 1984, Blanshard 1987). The granules exist in various shapes and sizes. The size of granules range from sub-micron of chloroplasts to over 100 μm of potato and canna (French, 1984). Shape of starch granules vary from sphere, disc, polyhedron, "oyster-shell" irregular, to mention a few (Banks & Greenwood 1975, French 1984, Blanshard 1987). The diameter of maize starch is about 2 to 30 μm, and exist as angular, polygonal or spherical in shape (Kent, 1983).

2.4.5.2 Composition of Starch

Starch granule is heterogenous in composition. Basically it comprises of two structurally distinct polysaccharides - amylose and amylopectin (Banks and Greenwood 1975, French 1984, Galliard & Bowler 1987). Some starches however contain a third polysaccharide - a short chain amylose (Banks & Greenwood, 1975). Amylose, the smaller of the two, is essentially linear containing 1000 to 10,000 1 - 4α - glucose units (French 1984, Galliard & Bowler 1987), except the large amylose which is slightly branched (Kjooberg & Manners 1963, Banks & Greenwood 1975, Shannon & Garwood 1984). Amylopectin is highly branched and contains about 100,000 1 - 4α and 1 - 6α- glucose units (Galliard &

Bowler, 1987). Amylopectin is the principal crystalline component of the starch granule (Banks and Greenwood, 1975). The proportion of amylose to amylopectin in starch granules differs considerably depending on the species and cultivar from which it is isolated (Shannon and Garwood, 1984). In general the percentage of amylose is 11 to 37%, the remainder being amylopectin (Deatherage *et al.*, 1955). Waxy maize starch however contains less than 1% (w/w) (Blanshard, 1987).

2.4.5.3 Gelatinization

Dry starch granules absorb water and undergoes limited swelling when suspended in water. This process is reversible (Hellman *et al.*, 1952), exothermic (Winkler and Geddes, 1931) and is suspected to be associated with the amorphous region of the granule. When the moisture content of the granule is greater than 20% further absorption of moisture with concomitant swelling of the granule requires heat input (French, 1984). The application of heat to the starch suspension results in quick absorption of water and swelling of granules. Above a characteristic temperature (called the gelatinization temperature) irreversible swelling of the starch granules occur leading to loss of crystallinity, order and solubilization of amylose (Blanshard, 1987).

Although the process of absorption of moisture by starch granules before the onset of gelatinization is reversible, prolonging the process can alter the starch-water complex leading to a permanent change in the internal structure of the granule (Gough & Pybus, 1971).

2.4.5.4 Traditional Theory of Gelatinization

Glicksman (1969) gave the traditional explanation of the phenomenon of starch gelatinization. According to Glicksman the molecules in starch granules are held together by hydrogen bonds. On heating an aqueous suspension of starch granules a critical temperature (gelatinization temperature) is attained where the system has sufficient energy to initiate weakening of the hydrogen bonds. More water is absorbed by the granules leading to swelling and loss of birefringence. Further heating causes disruption of the hydrogen bonds, as water molecules becomes firmly attached to the hydroxyl sites, leading to extensive swelling of the granules. As a result of the progressive swelling of the granules the molecules solubilizes causing an increase in paste consistency. When fully hydrated starch molecules become separated and diffuse into the aqueous medium.

For a concentrated slurry of starch, the granules swell until all the water has been imbibed. Granules continue to absorb more heat and become more susceptible to both mechanical and thermal breakdown. The highly swollen starch granules having occupied the entire volume will permit starch molecules which had earlier diffused into the surrounding aqueous medium to diffuse back, thereby altering the nature of the system into a gel-like mass held together by associative bonding.

2.4.5.5 Measurement of Pasting Viscosity

Changes in viscosity of starch suspension during gelatinization can be studied with the aid of the Brabender Viscoamylograph.

Typical Brabender temperature programme and viscosity curve for maize is shown in figure 2. From the amylograph, six important points are recognized (Zobel, 1988).

a. Pasting temperature - which is the initiation of paste formation;

b. Peak viscosity - the temperature at which maximum viscosity is attained;

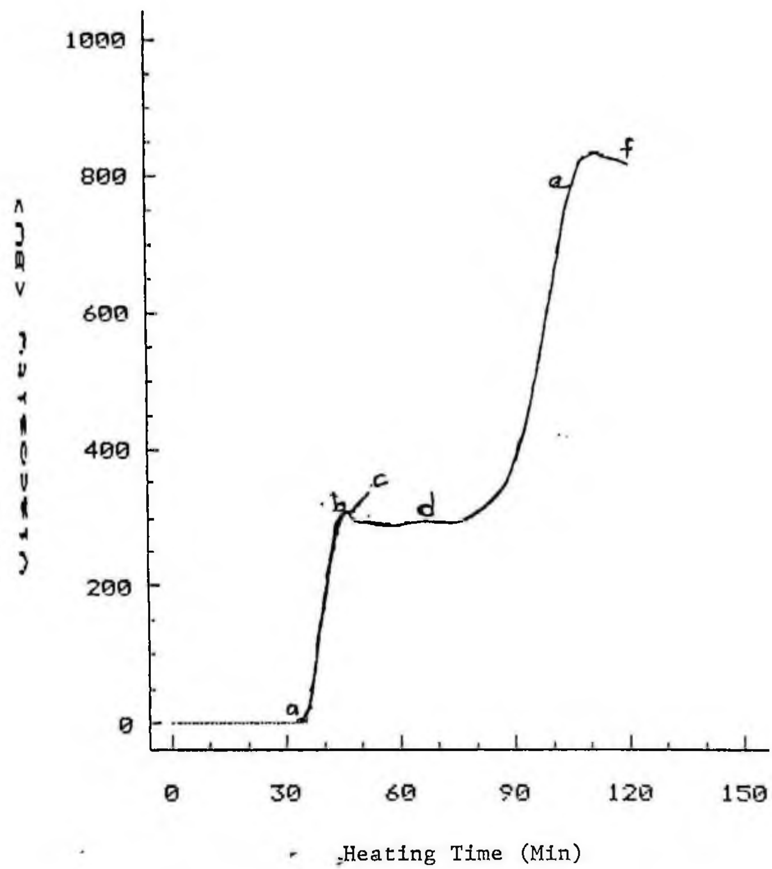
c. Viscosity at 95°C - which is a reflection of the ease of cooking the starch;

d. Viscosity at 95°C hold - which is a reflection of paste stability;

e. Viscosity at 50°C - an indication of (extent of) retrogradation

f. Viscosity at 50°C hold - indicates the stability of paste.

Fig. 2 Amylograph Pasting Curve for Slurry of Maize Dough.


1000
800
600
400
200
0
0
30
60
90
120
150
a
b
c
d
f
Heating Time (Min)

2.4.5.6. Increase in Viscosity Associated with Gelatinization

Traditionally the increase in consistency (viscosity) associated with gelatinization of starch was attributed to granules absorbing more water as they swell and thereby increasing the chances of coming into contact with each other (Miller *et. al.*, 1973). However, present findings indicate that many factors account for this phenomenon. Miller *et al.*, (1973) investigated the increase in viscosity associated with gelatinisation using light micrographs and scanning electron microscope, and showed that maximum viscosity of wheat starch suspension occurred after most granule swelling ceased. They observed that the increase was due to exudate which could be seen as a filamentous network. In situations where no filamentous network was observed there was no significant increase in viscosity. They suggested that there was a correlation between the amount of exudate and the pasting viscosity. Zobel (1984) investigated the effect of cooking and hold times on pasting viscosities of corn and tapioca starches. Both starches showed less cook-out (95°C hold) and higher consistency (50°C and 50°C hold) with shorter time. These findings seem to contradict the view that paste viscosity is largely a function of the exudate, since longer cooking time, by reasoning, should show a higher viscosity. Goering et *al.*, (1975) in studies on barley starch also failed to establish a relationship between the total amount of solubles and pasting viscosity.

3.0 MATERIALS AND METHODS

3.1 MATERIALS

The local variety of maize was used in the research. The grain was obtained from Crop Research Institute, Kumasi. Maize samples were kept in the coldroom (5°C) over the duration of the research.

3.2 METHODS

3.2.1 Field Survey

The research was carried out in 9 selected communities in the Accra - Tema metropolis of Ghana. These communities were selected based on purposive sampling (on prior knowledge that there is active *komi* processing activity). *Komi* processors were then selected from these areas by the random sampling technique. The data was collected by means of well designed questionnaire (Appendix 1) and interview schedules conducted in a language native to the respondents. The communities that fell into the sample are shown in Table 5.

Table 5 Community by Number of Respondents

Area	Name of Community	No. of Respondents
Accra	Mamprobi/Chokor	6
	Madina	5
	Bubuashie	5
	North Kaneshie	5
	Teshie	5
	Accra Central	5
	Achimota	5
Tema	Community One	6
	Community Two	5
Total	9	47

3.2.2 Laboratory Studies

3.2.2.1 Effects of Soaking, Initial Moisture and Fermentation on the Physicochemical Properties of Maize Dough

Part of the maize was milled twice with a disc attrition mill (Agro Grinding Mill, No.2A, India) into fine particle size meal without prior soaking. The rest of the maize was divided into two, soaked in excess water for 24 and 48 hours respectively, and milled twice into fine particle size meal using a disc attrition mill (Agro Grinding Mill No.2A, India). Samples of dough of initial moisture contents of 45%, 50% and 55% were prepared from each meal by addition of the appropriate amount of water (based on the initial moisture of each meal) and mixed thoroughly. The dough samples were allowed to undergo spontaneous fermentation at room temperature (29°C) for 3 days.

Experimental Design

Experiment was set up as a factorial in a completely randomised design. Principal factors investigated in the experimental design were:

i. initial moisture content of dough 45%, 50%, 55%;

ii. soaking time of maize : 0, 24, 48hr;

iii. fermentation time of dough : 0, 6, 24, 48, 72 hr

Forty-five treatment combinations (3 x 3 x 5) were obtained. The experiment was done in duplicate. Samples were evaluated for Moisture, pH, Starch, Total Titratable Acidity, Soluble sugars, and Brabender Cooked Paste Viscosity. Also evaluated was damaged starch of the meal.

The data was subjected to multiple regression analysis. Independent variables considered were

a. initial moisture content;

b. soaking time and

c. fermentation time.

The dependent variables were : starch content, Total Titratable acidity, pH and Soluble sugars.

3.2.2.2 To Establish Optimum Conditions For Titratable Acidity, pH and Cooked Paste Viscosity of Maize Dough Using Response Surface Methodology

Maize (local variety) was cracked using the disc attrition mill (Agro Grinding Mill, No.2A, India), and soaked in water at constant temperature of 45, 55 and

60°C in a water bath (Grant Instruments (Cambridge) Limited, Barrington, Cambridge, CB2, 5QZ, England) for varying periods of time (20, 30, 60 and 90 min). They were milled into fine meal using a disc attrition mill (Agro Grinding Mill, No.2A, India). The meals were divided into three equal portions each, and each portion made into dough (using the traditional process described by Bediako-Amoa 1973, Sefa-Dedeh and Plange, 1989) of initial moisture content 45%, 50% and 55% based on the initial moisture content of each meal. Dough samples were allowed to undergo spontaneous fermentation for 3 days. Fermentation was carried out in plastic containers at room temperature (29°C).

Design of Experiment

Experiment was set up as a factorial in a completely randomised design. Principal factors investigated in the design of experiment were :

a. soaking temperature : 45°, 55° and 60°C;

b. soaking time of maize : 20, 30, 60 and 90 min;

c. initial moisture of dough : 45%, 50% and 55%;

d. fermentation time of dough : 0, 24, 48 and 72 hr.

The experiment was done in duplicate and samples evaluated for Moisture, pH, Total Titratable Acidity and Viscosity.

The data was subjected to multiple regression analysis. Independent variables considered were :

a. soaking temperature

b. initial moisture content

c. fermentation time

d. soaking time

3.2.3 Chemical Analysis

3.2.3.1 Moisture Determination

Moisture content of maize meal and dough was carried out in one- and two-stage drying using American Association of Cereal Chemists (A A C C) method 44-15 (A A C C Approved Method, 1976) based on oven drying at 130°C for 60 min.

3.2.3.2 pH and Total Titratable Acidity

pH was determined on 5% aqueous suspension of dough. The dough was dispersed in carbon dioxide free distilled water to form suspension and swirled using an orbit shaker (Lab-line Instruments Inc. Melrose Park Iu.) at 150 r.p.m. for 30 min. It was centrifuged at 3,000 r.p.m. for 10 min and filtered through Whatman #4 filter paper, discarding the first 10 mL. The pH of filtrate was then determined (pH meter : Model HM-305 TOA Electronics Limited, Tokyo, Japan).

Total Titratable acidity was determined by diluting 25 mL of the filtrate in 50 mL of distilled water and titrating against 0.1M NaOH using phenolphthalein as indicator.

3.2.3.4 **Damaged Starch**

Damaged starch was determined using American Association of Cereal Chemists (A A C C) method 76 - 30A (A A C C Approved Method, 1971). Amyloglucosidase (agidex powder containing kieselguhr as diluent, from Aspergillus) with an enzyme activity of 3,000 unit/g manufactured by British Drug House Chemical Limited (Poole, England) was used.

3.2.3.5 **Viscosity (Brookfield Synchro-lectric Viscometer)**

Preliminary studies were carried out to determine the best experimental conditions for the use of the Brookfield viscometer for monitoring the viscosity of cooked slurry of dough. Factors evaluated were concentration of dough slurry, temperature for measuring viscosity and spindle type and speed. The experimental conditions were:

i. concentration : 5%, 6%, 7%, 8%, 10%

ii. temperature 50°, 60°, 70°, 80°, 90°C

iii. spindle speed : 25, 50, 100 r.p.m.

iv. spindle number : 4, 5, 6.

The best process conditions were slurry concentration, 6%; temperature, 60°C; spindle type and speed, #5 at 100 r.p.m.

Six percent (dry weight basis) slurry of dough was cooked into porridge (temperature of porridge was 95° -

96°C) in boiling water accompanied by manual stirring at moderate speed. The porridge was allowed to cool to 60°C and viscosity measured using Brookfield Synchro-electric Viscometer (Model RVT, Cooksville, Ontario, Canada) at 4 different locations and depths.

3.2.3.6 Pasting Properties (Brabender Viscoamylograph)

Pasting characteristics of the dough samples were determined with a Brabender Viscoamylograph (Viskograph PT 100, Brabender OHG Duisbuirg, West Germany) equipped with 700 cmg sensitivity cartridge. Five hundred millilitres of slurry (10% dry weight basis) was prepared as follows; the appropriate weight of dough based on the moisture content of the dough was homogenised in a waring blender at moderate speed for 10 sec into slurry by the addition of water. The slurry was heated at 1.5°C/min from 25°C to 95°C, held for 30 min at 95°C, cooled at 1.5°C/min from 95°C to 50°C and held at 50°C for 15 min. The slurry was stirred (bowl speed) at 75 r.p.m.

3.2.4 Establishing Optimum Conditions for Total Titratable Acidity, pH and Viscosity of cooked Maize Dough

Introduction

Response surface methodology (RSM) has been defined as a set of mathematical and statistical methods used when a large number of input variables in an experimental system influence the response of the system. The input variables are assumed to be subject to the control of the experimenter. In using this tool the aim of the experimenter is to:

a. establish a suitable approximating function which will enable prediction of future response,

b. determine which values of input variable produces the most favourable response.

The assumptions in response surface methodology are :

i. the response Z depends on the input variables X_1, X_2 ..... X_n

ii. input variables can be controlled with negligible error

In general, $Z = f\ (X, X_1\ \ldots\ X_n)$

where the form of f is unknown.

Multiple regression models were established using a stepwise multiple regression program. These were used in estimating the effects of the independent variables on the response variable. Three dimensional response surface plots were prepared from the regression models.

3.2.5 Data Analysis

All the statistical analysis were accomplished through the use of Statgraphics Software (Graphic Software System, S.T.C.C., Inc., Rocksville, Maryland, U.S.A.)

4.0 RESULTS AND DISCUSSION

4.1 Social Characteristics of Respondents

Majority (37 or 78.7%) of the total respondents of 47 were Gas (natives of Accra), 6 (12.8%) Fantis, 3 (6.4%) Ewes and 1 (2.1%) Grushie. Another glaring phenomenon was that *komi* processing is significantly a female occupation (Figure 3). This explains why sex of respondents was totally feminine. It also shows the predominant contribution of women to food processing in Ghana. Some of the women attested to the fact that their young sons and nephews and in some cases loving husbands lend hands in some aspects of the *komi* making process. Unit operations where males play a supportive role include:

a. preparation of dough
b. preparation of glutinous paste
c. *aflata* making
d. moulding and packaging

Milling operation is mainly the work of men. Information was also given regarding the emergence of some male *komi* processors in the system in recent times, but this study could not identify any in the sample. It is hoped that a future investigation might identify and include some male processors.

In order to give this study a sociological perspective it became necessary to probe into the

Fig. 3 Komi processing is essentially the work of women.

social background of respondents. These had to do with their age, educational level, marital status, number of dependants and working experience.

4.1.1 Age Distribution of Respondents

Table 6 shows the age range of the respondents. All the processors were adults. However there was information that some teenagers are involved in the business. This assertion was given credence by the fact that a respondent in the 20-29 age group has been in the business for as long as 14 years. Out of a total coverage of 47 respondents 32 (68.1%) were below 50 years of age. Of these adults as many as 12 (37.5%) were in their middle adulthood (30-39 age range), while 11 (34.4%) fell in the late adulthood (40-49 age range). There were also 9 young adults in the 20-29 age group.

Table 6 Age by Educational Level of Respondents

Age Range	None	Primary	Middle	Total	Percent
20 - 29	1	4	4	9	19.2
30 - 39	3	4	5	12	25.5
40 - 49	7	1	3	11	23.4
50 - 59	8	1	1	10	21.3
≥ 60	5	0	0	5	10.6
Total	24	10	13	47	
Percent	51.0	21.3	27.7		100

The trend portrayed in Table 6 is that as people aged they stayed away from the *komi* business. Some old ladies reacting to this situation where there was less aged people in the *komi* processing business remarked that "staying with the fire all that long combined with the laborious nature of the operations was death to the old." This perhaps explains why the number of *komi* processors reduced to 10 (21.3%) and 5 (10.6%) in the age groups of 50-59 and 60 and above respectively. Only one aged woman of 80 years old was still in active processing. It is a common practice that as mothers aged they pass over the *komi* enterprise to their daughters/grand daughters and receive royalties or a certain percentage of the profit which accrue from the business. Others enter into joint partnership with their daughters or grand daughters.

4.1.2 Educational Level

Educational level of respondents was generally low (Table 6). Of the total of 47 respondents as many as 24 (51.1%) have had no formal education. Of the remaining 23 (49.9%), thirteen (13) have had some education up to the middle school, while the rest (10) were in school up to the primary level. A further probe into the educational background of the respondents revealed that some of those in the middle school category were drop-outs and did not actually complete elementary form four. Even those who claimed to have completed elementary form four could appropriately be described as semi-literates, for it was very difficult for the researcher to interact with them in simple English. Invariably they had to seek some educated family members or in some cases their educated children to assist in establishing the identity of the researcher. None of the respondents have had post elementary education. That there was a high number of processors with no formal education in the age range 50 - 59 and 60 and above, could be explained by the fact that female education (in Ghana) is a recent phenomenon. The implication of this situation (low educational level of *komi* processors) is that issues related to technology transfer and adoption will require the demonstration approach.

4.1.3 Marital Status

Another social phenomenon that was investigated was the marital status of the respondents. From Table 7 one realises that a very significant number of 38 (80.8%) of a total of 47 respondents were married. In all there was only one unmarried person while 3 (6.4%) were divorced and another 5 (10.6%) were widowed.

4.1.4 Operational Status

All the processors were operating on commercial basis. The majority (85.1%) were processors-retailers while the rest (14.9%) were processors. The latter hired the services of agents who retail the products for a commission ranging between 16.7% to 23% of product sold.

Table 7 Age by Marital Status of Respondents

Age Range	Marital Status					
	Married	Single	Divorced	Widowed	Total	Percent
20 - 29	9	0	0	0	9	19.2
30 - 39	11	1	0	1	13	27.7
40 - 49	9	0	2	0	11	23.4
50 - 59	6	0	1	2	9	19.2
≥ 60	3	0	0	2	5	10.6
Total	38	1	3	5	47	
Percent	80.9	2.1	6.4	10.6		100

Although the findings of the investigation indicated that all the *komi* processors operate on commercial basis, it was learnt that some also operated on subsistence level. It is hoped that further investigation will attest to this claim.

The traditional *komi* processing industry is home-based (Figure 4), and owned and managed by the household. The enterprise serves the dual purpose of generation of income, and food for the family. In instances of single parenthood or unemployed husbands the business becomes the sole source of household income. In addition to eating part of the *komi* intended for sale, part of the dough (intermediate product for making *komi*) is also used to prepare other maize products like porridge, *etsew* or *banku* for household use. For some of the processors, particularly those who make small quantity per batch, *komi* processing only serves as an additional occupation to the main means of livelihood.

Fig. 4 The Komi industry is a small-scale home-based enterprise.

To assess the proportion of household income that comes from *komi* processing, respondents were asked to indicate their contribution (excluding the payment of utilities such as electricity and water bills and rent) towards household upkeep. Out of the total coverage of 3 respondents 20 (46.5%) indicated that their contribution towards household upkeep ranged from 50%-70%, 17 (39.5%) contributed between 80% - 100% and 5 between 20% - 40%. One of them indicated that she spends the income on her needs only.

4.1.5 Source of Finance

The *komi* industry is heavily dependent on private financing. A greater number (18 out of a total of 46) of *komi* processors prefinanced their enterprise with credit input of maize from private food suppliers. Ten persons (21.7%) used their personal resources as capital, while 8 persons each obtained money from their husbands and mothers. Two of the *komi* processors also financed their business with assistance from their grandmother and mother-in-law respectively.

4.1.6 Acquisition of Trade

A unique feature of the *komi* processing industry is that transfer of skills is informal in approach. The commonest was acquiring the trade by assisting a *komi* processor (Table 8).

Table 8 The Mode of Acquisition of Trade by Respondents

Mode of Acquisition	Number of Respondents	Percentage
1. On the job training		
Mother	26	55.3
Grandmother	8	17.0
Friend	2	4.3
Guardian	8	17.0
2. Observation	3	6.4
Total	47	100

Children or wards acquire the skills of the trade as they assist their mothers/guardians in their occupation. As much as 26 (55.3%) of the 47 respondents learnt the trade from their mothers, 8 (17%) each from their grandmothers and guardians and 2 (4.25) from friends. However 3 persons claimed that they acquired the trade through observation. This minority took advantage of the prevalence of the trade in the community and took the pains to observe how it is done. After a time they decided to try their hands at it. They admitted to encountering difficulties at the initial stages of going into production, but with time managed to polish their skills on the job.

4.1.7 Support Personnel

Two categories of support personnel were identified - wage earners and non-wage earners. The non-wage earners include children, relatives, husbands and dependants of respondents. This group provide the bulk of human resource support to the *komi* industry. Out of the 45 respondents who received human assistance in their trade 30 (66.7%) depended completely on their children, relatives and husbands. Occasionally the non-wage earners are rewarded in kind. The remaining 15 (33.3%) of the respondents had employees working either full-time or part-time to supplement or complement the effort of the household hands. The part-time employees are assigned specific jobs for which wages are earned (Table 9). In contrast a full-time employee may be assigned any job related to manufacture of *komi*. In addition to earning wages, fringe benefits in the form of free meals (of *komi*) are enjoyed by almost all employees. Table 9 indicates that employees are predominantly (24 out of total of 26) part-time workers. The indication is that certain activities tend to attract more employees than others. A greater proportion (10 or 38.5%) of the part-time employees were engaged in the preparation of glutinous paste and *aflata*, 8 (30.8%) in moulding and packaging, 3 (11.5%) in preparing package material for use, 2 (7.7%) in the washing of dishes and 1 (3.8%) in fetching of water. It was learnt that the more strenuous unit operations particularly the preparation of glutinous paste and *aflata* are reserved for the young and energetic, while processes which require less strenuous effort such as preparation of the package material for use is usually the work of the aged. Only

2 respondents out of the total coverage of 47 were not receiving any form of assistance in their work.

Table 9 Unit Operation Which Attracts Paid Labour

Employee Status	Type of Work	Daily Wage (Cedis)	Number of Employees
Full - Time	Varies	¢1000.00	2
Part - Time	Preparation of glutinous paste & *aflata*	¢ 150 - 250.00	10
	Moulding & Packaging	¢ 200 - 300.00	8
	Preparation of packaging material	¢ 200 - 500.00	3
	Retailing	¢ 200 - 250 for every ¢1200 - 1250 of product sold	NA
	Washing/making dishes	¢ 200 - 300	2
	Fetching of Water	¢ 150	1

NA :- Not Available

4.2 Raw Material

Maize (*Zea mays*) is the predominant raw material in the manufacture of *komi*. The other raw materials used are corn sheath for packaging and salt for improvement in the taste and flavour of the product. The acquisition of maize for the manufacture of *komi* is subject to stringent subjective quality control practices. Processors had set standards which guide them in the purchase of maize. It was realised that although there are many varieties of maize on the market (Table 4), respondents tend to be very particular about the variety of maize used. The indication was that the indigenous local variety is preferred over the improved varieties (commonly referred to as 'Agric.'). Some reasons given by respondents for their choice include:

i. good swelling and pasting characteristics during soaking and cooking,

ii. good water absorption properties on soaking and cooking,

iii. good product texture, taste and flavour,

iv. good yield of product and therefore higher profit margin, and

v. longer shelf-life of product.

Some of the improved maize varieties were described by respondents as being chaffy, having poor swelling and pasting characteristics on soaking and cooking, high losses during milling, poor product texture, taste and flavour, and low yield of product and hence low profit margin .

Secondly, *komi* processors go in for white and clean maize with very little or no insect/rodent/fungal damage which possess the typical maize flavour. "Good quality maize", they said, "is the key to good quality *komi*."

4.2.1 Purchase of Raw Material

Maize is purchased from various market centres in the Accra-Tema metropolis. This included the Kaneshie, Makola, Madina, Mamprobi and Kantamanto markets in Accra, and the Community One market in Tema. Others purchase maize from private food contractors who obtain their maize supplies from the Techiman, Asasewa, Bodwiase, Sunyani, Kumasi or Somanya markets.

The mode of purchase of maize is by cash, on credit or a combination of the two (that is, sometimes on credit and other times with cash). Majority (29 or 61.7%) of the respondents (47 in number) received maize on credit, 12 (25.5%) by a combination of cash and credit and 6 (12.8%) made purchases with cash. This finding is different from that reported by Sefa-Dedeh and Plange, (1989). They reported that 10 (76.9%) and 2 (15.4%) out of the total coverage of 13 respondents made maize purchase by cash and on credit respectively, while 1 (7.7%) purchased the maize by cash and sometimes on credit.

Credit purchase of maize do not require collateral security as a pre-condition. Oral contracts are made which require the recipient to make full payment or part-payment every week, fortnight or month. Others are expected to make payment only after the products have been sold.

The maize (maxibag) is usually priced depending on the mode and terms of purchase. Credit purchases are priced higher. An "interest" of up to ¢3,000 may be added to the baseline price depending on the time of payment.

It was observed that purchasing of maize in bulk by respondents is the rule rather than the exception. One advantage of purchasing maize in bulk is that it cost less.

The other raw materials (salt and corn sheath) are paid for in cash. These materials are easily obtainable on the various markets in the Accra-Tema metropolis.

4.3 Processing of Komi

An important factor in this study is the technology of application in *komi* processing. This was to enable the simulation of the processes under laboratory conditions for the establishment of the scientific basis of the unit operations used in processing, the nutritional value and the storage life of the product.

4.3.1 Variations in Technology

The technology for the manufacture of *komi* remains essentially identical from one processor to another. Variations however were encountered in the following operations:

i. Steeping, fermentation and boiling: in terms of the time required for maturation of the process,

ii. Dough preparation: the amount of water added to the meal,

iii. *Aflata*: the ratio of raw to cooked fermented dough.

It was learnt on the field that varietal differences in the maize used is primarily responsible for the differences in the processes. This effect is manifested in the following:

a. a longer soaking time is required for maize of hard texture,

b. a processor may alter the ratio of raw to cooked fermented dough in *aflata* to suit the characteristics of the maize used,

c. a relatively shorter time is required for boiling *komi* made from maize of poor swelling power (Table 10).

Table 10 Comparison of Duration of Some Unit Operations in *komi* Processing by Various Investigators

Operation	DURATION OF OPERATION (Hr)			
	Present investigation	Ofosu (1967)	Bediako-Amoa (1973)	Sefa-Dedeh & Plange (1989)
Soaking	18 - 48	24 - 72	24	18 - 48
Fermentation	24 - 96	72	48 - 72	48 - 72
Boiling	1 - 4	3 - 4	2 - 3	1 - 2.5

Variation also exists in time required for a unit operation due to the batch size. This affects processes such as: cleaning of maize, preparation of glutinous paste, moulding and packaging, and boiling of product. A strong correla-tion appears to exist between the length of time for boiling of *komi* and the proportion of raw dough in *aflata* (Table 11).

Table 11 Relationship Between the Proportion of Raw to Cooked Fermented Dough in *Aflata* and the Time Required to Boil *Komi*

	Proportion of Cooked to Raw Dough		
	Raw > Cooked	Raw = Cooked	Raw < Cooked
Respondents (%)	37.2	27.9	34.9
Mean Boiling Time (hours)	2.69 ± 0.90	2.37 ± 0.60	2.18 ± 0.88

The greater the proportion of raw dough in the *aflata* the longer the boiling time of *komi*. Analysis of variance of the data showed a significant ($p \leq 0.05$) effect of proportion of raw fermented dough in *aflata* on boiling time.

4.3.2 Detail Process

Maize is cleaned by hand picking and winnowing, soaked in water (Figure 5) for 18 to 48 hours and milled into fine meal. The meal is made into a dough by addition of sufficient quantity of water and allowed to undergo spontaneous solid-state fermentation (Figure 6) at room temperature. In rare situations the dough

Fig. 5 Steeping of Maize being carried out in various containers.

Fig. 6 Maize dough undergoing spontaneous solid-state Fermentation in uncovered deep containers.

is inoculated with fermented maize dough to accelerate the process of fermentation. Utilization of dough commence after 24 hours of fermentation and is continued till all the dough is used up a process which may last for 3 to 4 days. All this while dough fermentation continues. Similar findings on the preparation of maize dough have been reported (Bediako-Amoa 1973, Plahar and Leung 1985, Sefa-Dedeh and Plange 1989). A portion of the fermented dough is slurried and cooked with concomitant stirring and kneading (Figure 7) into a glutinous paste. According to Bediako-Amoa and Austin (1976) this action is essential for the development of the desired paste characteristics. Water is added occasionally to the glutinous paste to control its thickness. Salt (solution) is added when the paste is cooked.

The glutinous paste is then transferred in parts into a wooden receptacle (*aflata* mixer) with raw dough at the base. Each transfer of dough is overlaid with raw dough to form a mass of interspersed raw and cooked fermented dough (Figure 8). The mass is mixed hot using a wooden stirrer to form *aflata* (Figure 9). The *aflata* is allowed to become lukewarm and remixed thoroughly using the fingers.

Variations were observed in the ratio of cooked to raw fermented dough used in the preparation of *aflata*. Some of the ratios encountered are: 1:2, 1:1, 2:1, 2:3 and 3:2. A greater proportion (37.2%) of *komi*

Fig. 7 Preparation of glutinous paste is the most difficult operation in the Komi process.

Fig. 8 **A mass of cooked and raw fermented dough before mixing to form *aflata*.**

Fig. 9 ***Aflata* being moulded into desired sizes for packaging**

processors used more of raw to cooked fermented dough to prepare *aflata*, 34.9% used more of cooked to raw dough and 27.9% used equal proportions of cooked to raw dough (Table 11). Bediako-Amoa, (1973) and Sefa-Dedeh and Plange (1989), reported that equal proportions of cooked to raw fermented dough is used in the preparation of *aflata* for *komi* manufacture. The present findings indicate that a significant proportion of *komi* processors use ratios 1:2, 2:1, 2:3 and 3:2 of cooked to raw fermented dough in making *aflata*.

Aflata of desired size is placed in a wet corn sheath (Figure 10A), additional sheaths are added and the product wrapped meticulously with adjacent sheaths overlapping (Figure 10B). The loose tapered ends of the sheaths are twisted (Figure 10C) and inserted into the product through the side (Figure 10D). A little bit of the *aflata* is stuck to where the twisted sheath is inserted. The product is then patted into the desired shape. And this could be cylindrical to spherical (Figure 11). Packaged products are packed (with the exposed end facing downwards) into aluminium pot or aluminium container layered at the base with corn sheath (Figure 12). The pack is overlaid with corn sheath, jute sack or cotton cloth and polythene after water is added to fill up to about a third of the pot. Products are heated vigorously during the first 90 min, moderately for another 60 min and then gently for 30 to 60 mins (Figure 13). Additional water is

Fig. 10 Stages in the Packaging of Komi:

a. A desired size of *Aflata* is placed in maize sheath.

b. *Aflata* is packaged with maize sheath overlapping

Fig. 10

c. Loose tapering ends of maize sheath is twisted.

d. Twisted end is inserted in the product through the side.

Fig. 11 Packaged product is spherical to cylindrical in shape with one end exposed.

Fig. 12 A layer of maize sheath at the base of aluminium pot. This helps prevent Komi from getting burnt and sticking to the base.

Fig. 13 Aluminium pot charged with packaged product being cooked on traditional stove

usually required during boiling to ensure a well cooked product. Flow diagram for the manufacture of *komi* is shown in Figure 14. This is similar to that reported by Ofosu (1967), Bediako-Amoa (1972) and Sefa-Dedeh and Plange (1989) except the processes of charging and recycling of the product which are absent in the earlier reports.

4.3.3 Critical Operations in *Komi* Processing

It was realised that quality consciousness is a hallmark of all *komi* processors. This phenomenon is motivated by both monetary gains and the quest for fame. Almost every processor harboured the secret ambition of being referred to as the best *komi* processor and also to stay in business in view of the competitive nature of the market. In order to ensure this, particular attention is given to some operations considered (by processors) as critical for achieving good quality *komi* (Table 12).

In an earlier report Sefa-Dedeh and Plange (1989), enumerated five operations - steeping, dough making, fermentation, preparation of *aflata* and boiling as important for achieving the desired quality of *komi*. In this study four other operations in addition to what was reported by Sefa-Dedeh and Plange (1989) were found to be important for the production of good quality *komi*. They are:

Fig. 14 FLOW DIAGRAM OF *KOMI* PROCESSING

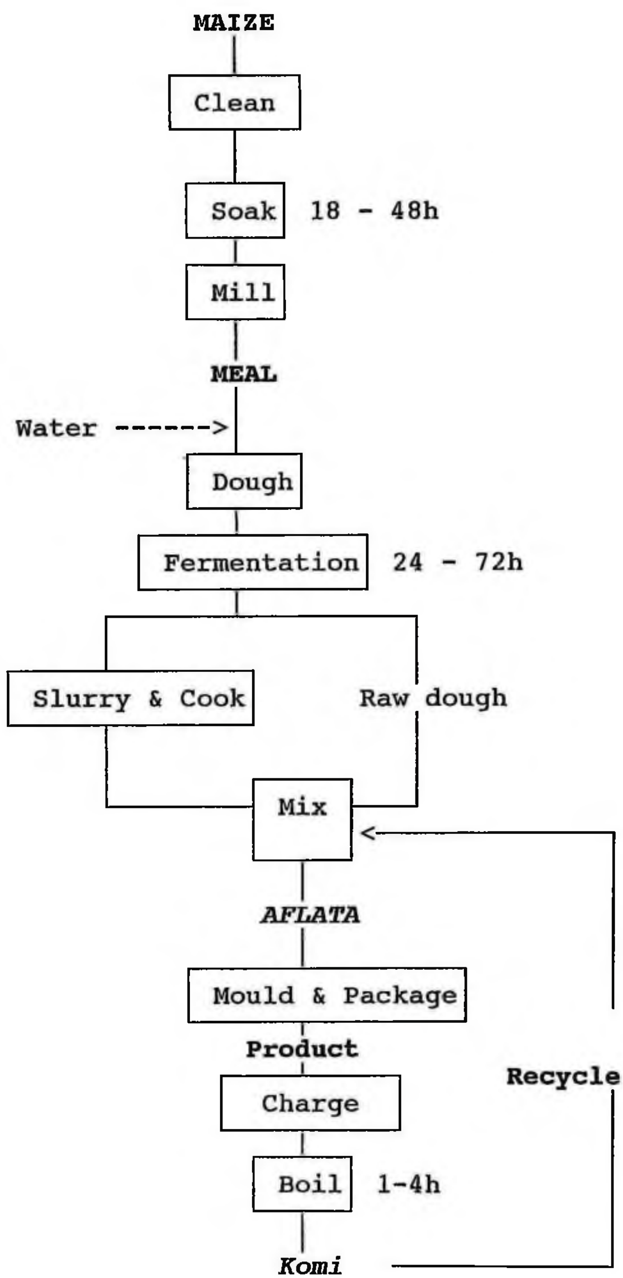


Table 12 Critical Operations and Practices for Achieving Good Quality *komi*.

Operation	Importance	Precaution
Cleaning of maize	a. Improves colour, taste and flavour of product	-
Soaking	a. Softens the maize and ensures effective particle size reduction and thereby good texture of product b. Improves the taste and flavour c. Causes swelling of grain d. Initiation and enhancement of fermentation	-
Dough firmness	a. Affects shelf-life of the dough b. Affects flavour and taste	-

Operation	Importance	Precaution
Fermentation	a. Development of the right taste (sourness), flavour and texture b. Affects cooking time eg. long fermentation time reduces cooking time c. Improves paste consistency and yield of product	
Preparation of glutinous paste	a. Development of right consistency, texture and flavour b. Cause gelatinization of starch granules for binding raw dough at *aflata* stage	Product should not be lumpy
Aflata	Texture and taste development	a. Inadequate mixing of the mass results in product with jelly-like patches and soft spots. b. Right ratio of cooked to raw dough must be observed.

Operation	Importance	Precaution
Packaging	a. Prevent losses during boiling through leaching	-
Arrangement of product in receptacle for boiling	a. Ensures proper and uniform boiling (cooking) of *komi* b. ensures that packaging is intact during boiling of product	Products are packed closely with adequate spaces between adjacent ones to guarantee free flow of water from one layer to the layer above
Boiling of product	a. uneven distribution of heat (due to the direction of flow of wind) could result in uneven cooked product b. Vigorous heating during the initial 60 - 90 min is crucial for development of product texture.	

1. cleaning of maize
2. preparation of glutinous paste
3. packaging and
4. arrangement of product in receptacle for boiling.

Various reasons were given by respondents on why an operation is considered important in achieving good quality *komi*. Also given are some precautionary measures essential for the smooth running of the process (Table 12). Identical findings were made by Sefa-Dedeh and Plange, (1989). What is new is that :

i. soaking also causes swelling of grain and enhances solid-state fermentation of maize dough,

ii. Fermentation :

- increases the consistency of cooked dough, and also the product yield,
- affects cooking time, for example: prolonged fermentation reduces cooking time,

iii. Boiling - improves the flavour of product.

Call for Improvement in Process and Product Characteristics

It is of interest to note that respondents are aware of the inherent inefficiencies in the process and product characteristics and the need for improvement. Most of the unit operations were described as tedious, laborious and/or time consuming (Table 13). There were also issues of concern related to health which were found to be linked to processing. Complaints of severe chest pains, back aches and excessive loss of blood during menstruation were received from some of the respondents. Consequently, they (respondents) called for improvement in the process and product characteristics and expressed their readiness to cooperate with researchers in seeking solutions to

Table 13 Process Characteristics of *Komi*

Unit Operation	Problems	Suggested Improvement	Percent Respondents
All the processes	Tedious, laborious and time consuming	Processes should be mechanized	48.9 (23)
Cleaning of maize	Tedious, laborious and time consuming	a. Mechaniza-tion of process b. Availabi-lity of cheap labour	4.2 (2)
Milling	Milling centres are sited at distant places	Siting of more and uniform distribution of milling centres in the locality	-
Preparation of glutinous paste	a. Tedious and laborious b. Long exposure to heat results in excessive bleeding during menses	a. Operation should be mechanised b. Provision of convenient flour	14.9 (7)
Aflata	Operation is tedious and laborious	a. Mechaniza-tion of process b. Provision of convenient flour	14.9 (7)
Moulding and Packaging	Operation is tedious, laborious and time consuming	Mechanization of process	6.4 (3)
Boiling	Exposure to heat and smoke	Improvement in traditional stoves is required	10.6 (5)

these problems. Respondents further suggested the nature and form of improvement they want seen in the processes (Table 13).

Twenty-three (48.9%) out of a total of 47 respondents indicated that all the processes were laborious and time consuming, 7 (14.9%) each identified the preparation of glutinous paste and aflata as laborious and time consuming, while 5 (10.6%) felt that the exposure to heat and smoke during cooking posed serious threat to human health. Consequently respondents called for the mechanization of the processes, and more importantly, the provision of convenient flour. Majority (83%) indicated their readiness to use convenient flour when available, 12.8% were not in favour of the use of convenient flour because they felt it will be unprofitable, others think it is impossible to make such a product.

4.3.4 Equipment

Table 14 shows the various equipment used in the komi industry. The industry is heavily dependent on locally fabricated and manufactured equipment. The disc attrition mill and stoves made from used automobile engine blocks are the only equipment which are imported in part and whole respectively.

Almost all the locally made equipment are fabricated and manufactured by small-scale artisans in the metal, lumber and cane industries who operate in the countryside or/and cities. Artisans in the metal industries mainly operate from the cities and depend on metal scraps as raw material. The cane and lumber industries are often sited in the countryside where they depend on the rich natural vegetation for raw materials. The material

Table 14 Processing Equipment Used in Traditional Processing of komi and Current Prices

Equipment	Price (cedis) at June (1992)	Uses	Made Local (L) Foreign (F)	Life Span (Years)
Aluminium Pot	8,800-30,000 (depending on size)	i. Cooking of glutinous paste ii Boiling of product iii. Steeping of maize	L	2½ - 30
Aluminium Container	3,800.00	i. Steeping of maize ii. Mixing aflata iii. Fermentation of dough iv. Sale of product	L	½ - 6
Aflata mixer (wood)	3,000-5,000 (depending on size and material of make)	Mixing of Aflata	L	2 4
Wooden/ bamboo stirrer	500-800 (depending on size)	Stirring of slurry into glutinous paste and mixing of aflata	L	¼ 2
Woven-cane basket	300-500 (depending on size)	i. Draining of steeped water ii. Preparing corn sheath	L	½ 1
Plastic drum	5,000 8,000	i. Soaking of maize ii. Fermentation of dough	L	3 - 5
Plastic bucket	600 - 800	Fetching of water	L	1 - 2
Traditional stove (mud)	NA	Heating product	L	⅓ 1
Traditional stove (automobile engine)	3,000.00	Heating product	F	>10

used in the manufacture of an equipment usually determines its life-span (Table 14). It was discovered that the use of old engine block is becoming more popular among komi processors because of its longer life span. Furthermore, unlike the traditional stove which requires regular maintenance the automobile engine does not.

All the equipment used in the processing of komi except the disc attrition mill are owned and managed by the processors. Only 3 (6.4%) out of the total coverage of 47 respondents did not own aluminium pot. Of these 2 were hiring the pot at ¢500 and ¢600 per month, while the remaining person was borrowing from friends or relatives.

4.4 COST OF PRODUCTION

4.4.1 Cost of Equipment

A minimum of ¢22,000 is the estimated initial investment for commencement of komi production on a commercial scale. In practice however, a processor can start production with less the amount because the equipment are household equipment and can be easily borrowed or hired.

Cost Analysis

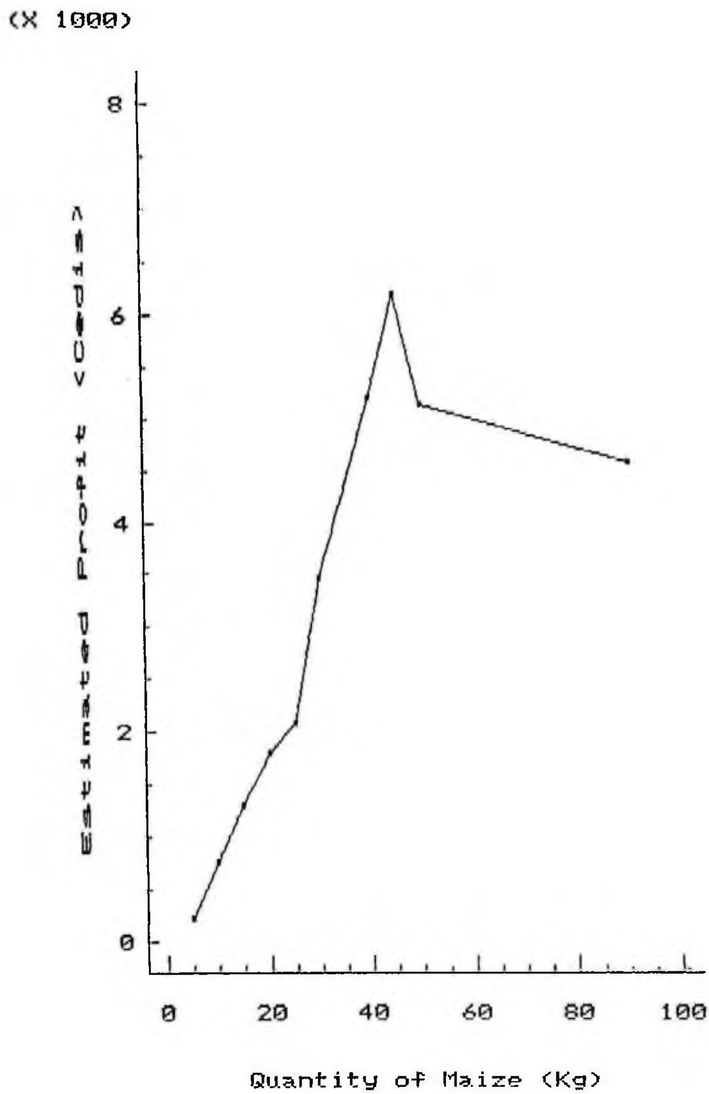
In the estimation of cost of production miscellaneous inputs such as tomato sauce, paper for wrapping products and water used were not considered. Also excluded is the overhead cost of production. The cost of production include inputs such as:

1. Raw material: maize, corn sheath, salt and fuel,
2. Services: transportation, milling and labour.

The estimated cost of production per maxibag of maize ranged between ¢19,000 - ¢33,900. The difference is due to variations in cost of raw materials, services and size of batch produced.

The relationship between profit level and quantity of maize (in kg) used per batch of Komi is shown in Figure 15. In general profit margin increases with increase in quantity of production. The shape of the curve could be due to an existence of economies of scale in the medium scale, and diseconomies of scale in the large scale sector.

Fig. 15 Estimated profit (cedis) per quantity of maize (kg) used in the production of batch of Komi.


(X 1000)
8
6
4
2
0
Estimated Profit (Cedis)
0
20
40
60
80
100
Quantity of Maize (Kg)

It appears that the small scale sector is too small to enjoy any significant economies of scale. Production is said to be characterised by economies of scale if when all input quantities are doubled, the quantity of output is more than doubled. Where production is characterised by economies of scale, large scale processors are likely to earn significantly more profit than small scale processors, provided steps are taken to effectively monitor the large number of departments and/or workers of the business. Furthermore, large scale production is normally associated with certain advantages that can significantly increase profit levels. These advantages include:

1. A high degree of specialization and consequently a more efficient utilization of resources/inputs;
2. Discounts on bulk purchase of inputs.

The above factors could account for the higher levels of profits enjoyed by the medium scale komi processors, compared to the small scale processors.

4.4.3 Marketing of Product

The sale of komi commences immediately after production. Product is sold at home, at the market, any convenient site easily accessible to the consumer, or by hawking. Similar findings were reported by Sefa-Dedeh and Plange (1989). What is new is that a significant number of respondents sell their product by hawking.

Prices of komi ranged from ¢30 to ¢50 depending on the size. This gives consumers a spectrum of choice in terms of quantity of product required for a meal. The price of product is not fixed.

It is largely influenced by cost of raw material. When there is a small increase in cost of raw material input, processors respond by reducing the size of product. However a significant increase in the cost of raw material input pushes up the price of the product.

The demand for komi is very high and respondents in general are satisfied with sales per day. Majority (59.5%) of respondents are able to sell the batch(es), of komi the same day most of the time, 27.7% sell all the products all the time and 12.8% are unable to sell the batch(es) the same day most of the time. None of the respondents was unable to sell the batch(es) of komi the same day all the time. Unsold product is sold the next day (sometimes at reduced prices), may be eaten at home (when the quantity is small) or recycled (when in large quantity). Product recycling is done at the aflata stage. Recycling involves mashing of the product into a mass after the packaging is removed and mixing with the uncooked and cooked fermented dough (aflata stage) (Figure 16). This way processors are able to reduce losses to the barest minimum. If a batch of komi is not sold on the second day it is recycled.

Fig. 16 Unsold Komi being prepared for recycling.

Marketing Strategies:

Shrewd marketing strategies and policies are employed by some (21 or 44.4%) respondents to attract and retain customers. One of such strategy is the extension of interest free credit packages with favourable terms of repayment. Under this credit scheme financially handicapped customers receive food on credit and repayment is made at the end of the month (in the case of salaried workers), after sale of catch (in the case of fishermen) and in rare situations at the convenience of the customer. The only prerequisite is that the beneficiary must be gainfully employed. Usually there is a limit to the amount of food the consumer can be credited.

On the whole beneficiaries of the credit scheme have good credit worthiness. In most cases beneficiaries repay promptly. Some however, make repayment stingily in which case the creditor will respond with threats and harassment to get the money paid. Others are unable or refuse to make payment and therefore lose such facilities. It was realised that instances of high rate of credit unworthiness on the part of some beneficiaries had compelled some komi processors to cancel the credit scheme altogether.

4.4.4 Seasonality Effect on Sale of Komi

The study indicated a seasonality effect on the sale of komi. Two major seasons were identified: (a) season of good sales and (b) season of poor sales. The major fishing season (July-August), Christmas and Easter seasons, Homowo festival, the lean season (February-June) and pay-day are associated with good sale of komi, whilst August-November (the bumper harvest of food), the season of Moslem Ramadan and middle to the last quarter of the month is characterised by poor sales (Table 15).

When sales are good processors take advantage of the increase in the demand for the product by increasing the size or/and frequency of batch. Out of a total coverage of 45 respondents 36 (80%) increased their production level, while the remaining 9 (20%) maintained their present level of production (to play it safe). Likewise, 43 (95.6%) of the processors reduced their output when sales are poor with only 2 (4.4%) maintaining their current level of production.Aside the normal direct sale of product to the public, respondents occasionally receive orders for bulk purchases. Such requests are made at occasions such as funerals or out-dooring and by customers travelling outside the country who take them along as presents.

4.4.5 Storage

The shelf-life of komi was found to be very short - 2 to 7 days. Processors attributed this condition to incomplete packaging of the product which exposes it to microbial attack. They buttressed their assertion by citing Fanti kenkey a product which has a longer shelf life because of complete packaging. Another cause for the short storage stability is the high moisture content of the product which favours the proliferation of microorganisms. Similar findings were reported by Sefa-Dedeh and Plange (1989). According to the respondents the shelf-life of the product is determined by an interplay of product quality and storage conditions. Some of the respondents

Table 15 Seasonality Changes in the Sale of komi

Season	Reason
Season of Poor Sales:	
Bumper food harvest (August - November)	Food is in abundance and at affordable price, hence consumers find it more economical to cook at home.
Festive Occasions a. Immediately after christmas b. Ramadan	a. Consumer effective demand is low due to excessive expenditure during christmas. b. Moslems are on a fast hence the demand for product is low.
Middle of the month	Purchasing power of salaried workers is terribly low.
Season of Good Sales:	
Lean Season (February - June)	Prices of food commodities are prohibitive, hence it seem more economical to buy komi.
Fishing Season (July - August)	komi is usually eaten with fried fish. When fish is in season the prices are affordable, hence customers can afford a good meal of komi and fish.
Festive occasions: a. Christmas b. Homowo c. Easter	a. Purchasing power of consumers are high b. Influx of visitors on such occasion leads to increase in the demand for the product c. Customers are busy enjoying themselves, hence will prefer buying instant food to cooking at home.
Pay-day	Effective demand of salaried workers is high.

indicated that a greater proportion of raw fermented dough in the aflata tends to prolong the shelf-life of komi. The best conditions for storage of the product is to keep in a clean container (covered) in an airy place, a refrigerator, or submerged under water. Intermittent heating of the product during storage helps prolong the product shelf-life. When these conditions are observed the product can last for 7 days.

4.4.6 By-product

'Otinshinu' (Ga) or cooked liquor is the by-product of komi. It is similar in consistency and appearance to thin porridge. Cooked liquor is eaten as snack, weaning food, or drank because of its curative properties. It is believed to relieve malaria, fever and jaundice or diarrhoea (a form of oral rehydration salt). It has no monetary value and is often discarded as waste.

4.4.7 How Komi is Eaten

Komi is eaten by people of all age groups. It is usually eaten as main meal with fried (or smoked) fish and sauce, stew or soup. It can also be eaten as snack in which case it is mashed and sugar added.

The use of komi as a weaning food for infants was found to be uncommon. Majority (54.3%) of the respondents indicated that komi is not used to wean infants, 39.1% indicated that it is or can be used to wean infants, and 6.5% said they are unaware of the use of komi as a weaning food. When komi is used as a weaning food it is administered in the mashed form or `as is' with soup.

LABORATORY INVESTIGATIONS

4.5 Effect of Soaking, Initial Moisture and Fermentation on the Physicochemical Properties of Maize Dough.

4.5.1 The Traditional Process

4.5.1.1 Water Absorption by Maize Kernel

The uptake of water by whole maize kernels during steeping is shown in Figure 17. The amount of water absorbed per unit weight of maize tends to increase with increasing steeping time. The moisture content increased from 14.34% in dry maize to 34.16% and 38.92% after 24 hours and 48 hours of steeping. About 4 times more water is absorbed by the kernel during the initial 24 hours of steeping than in the last 24 hours, for maize soaked for 48 hours. Akinrele (1970) has reported similar findings for maize.

Water absorption of seeds is linked to the inherent structure. The first barrier is the pericarp and the testa. The structure of the pericarp and testa affects the initial stages of water absorption. The latter stage of the process involves the uptake of water by macro-molecules, particularly the protein matrix (and to a lesser extent by starch and cellulose) of the endosperm.

Water absorption was increased significantly when the grains were cracked and steeped at elevated temperatures (Figure 18). What was achieved in 24 hours and 48 hours without cracking was achieved in 20 to 90 min. Cracking of the maize increased the surface area available for water absorption and exposed the

Fig. 17 Water absorption of whole maize kernels steeped at room temperature (30°C).

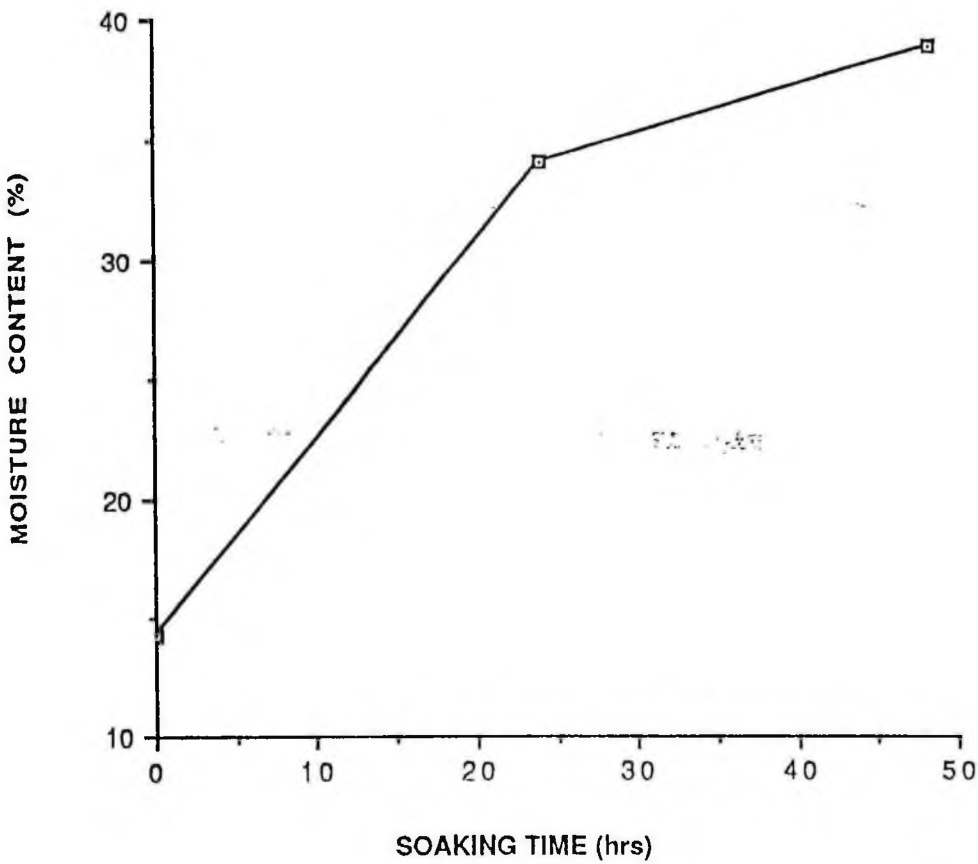
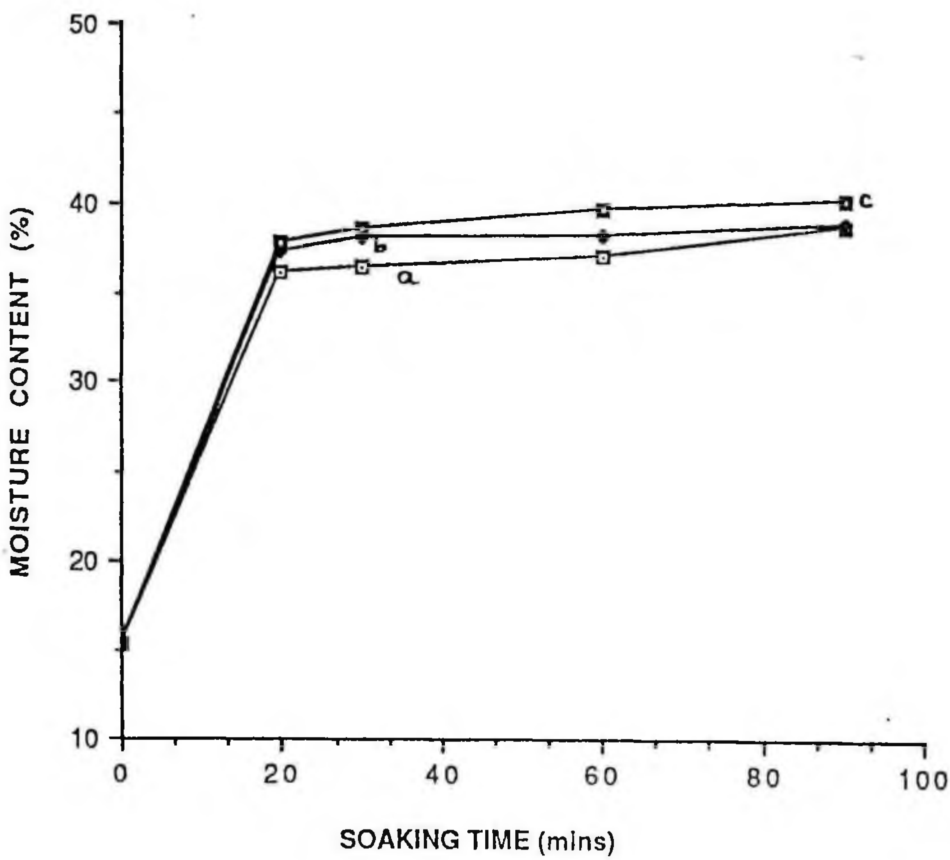

MOISTURE CONTENT (%)
40
30
20
10
0
10
20
30
40
50
SOAKING TIME (hrs)

Fig. 18 Absorption of water by cracked maize soaked at 45°C (A), 55°C (B) and 60°C (C)



MOISTURE CONTENT (%)
50
40
30
20
10
0
20
40
60
80
100
SOAKING TIME (mins)
a
b
c

endosperm to the water. In addition the limited barrier due to the pericarp and testa was reduced through cracking.

Water uptake was also found to increase slightly with increase in soaking temperature. The rate of water uptake in cracked maize ranged from 1.06 to 1.13 g/min/100g db for soaking temperatures of 45°C to 60°C at the initial stages of steeping; and 0.2 to 0.5 g/min/100g db in the final stages. Oguntunde and Adebawo (1989) reported similar findings in varieties of whole maize, sorghum and millet.

4.5.1.2 Rate of Moisture Loss

Data on loss of moisture from maize dough undergoing fermentation is presented in (Figure 19). Apparently some water is lost during fermentation. The amount of water lost and the rate of loss appear to increase with increase in fermentation time. Also affecting moisture loss is the initial moisture content of dough. More moisture is lost when the dough has low initial moisture. As the initial moisture is increased (in the range of 45% to 55%) less moisture is lost.

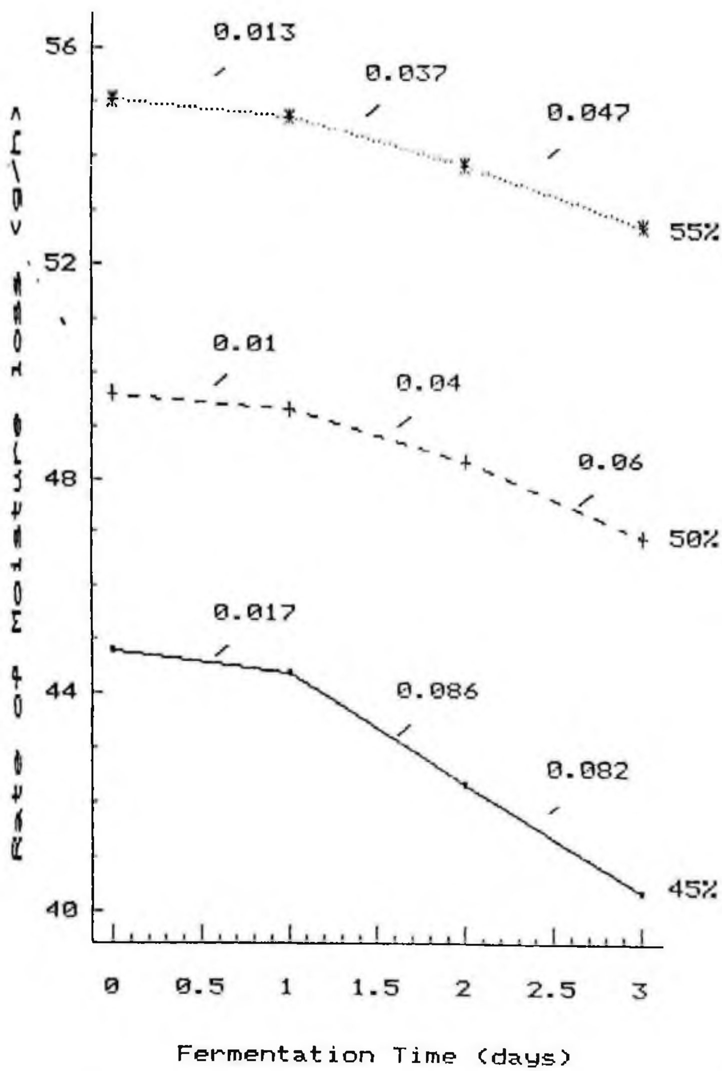
Analysis of variance of the data indicated a non-significant ($P \geq 0.05$) effect of fermentation time and initial moisture on moisture loss. From the data it can be concluded that the moisture loss from the fermenting maize dough is not influenced by fermentation time or the or the initial moisture.

Fig. 19 Effect of Fermentation on moisture content of maize dough.

Prefermentation treatment conditions are:

Soaking temperature: 30°C

Initial moisture of dough: 45%, 50% and 55%



Rate of Moisture loss, (g/h)
56
52
48
44
40
0.013
0.037
0.047
55%
0.01
0.04
0.06
50%
0.017
0.086
0.082
45%
0
0.5
1
1.5
2
2.5
3
Fermentation Time (days)

4.5.1.3 Starch Content

Table 16 suggests that starch content of maize increases during soaking. It increased from 67.64 g/100g db in dry maize to 72.3 g/100g db in maize soaked for 48 hours. The apparent increase in starch is due to the soaking process which causes leaching of soluble sugars from the grain, and increases the starch per unit weight of the maize. Similar findings were reported by Vivas <u>et al</u>; (1989) in soaked maize and sorghum.

Table 16 Some Characteristics of Meals/Flours Prepared From Maize

Treatment	pH	Starch Content [g/100g db]	Soluble Sugars [g/100g db]	Damaged Starch [%]	Moisture [%]
Dry	6.36	67.64 ± 1.15	6.12	5.10	14.34 ± 0.13
Steeped 24hr	6.23	69.52 ± 0.92	4.96	0.68	34.16 ± 0.25
48hr	4.90	72.30 ± 0.80	3.62	0.56	38.92 ± 0.15

On fermentation the starch content of maize dough decreased with time. This could be attributed to activities of amylase producing microorganisms (such as Corynebacteria) that break down starch into simpler sugars, releasing water in the process. Dough samples prepared from dry-milled maize had lower starch content than those prepared from wet-milled maize with the days of fermenta-tion. This might be due to the fact that starch content of the unfermented dough samples prepared from wet-milled maize was higher than those from dry-milled maize.

Analysis of variance of the data (Table 17) showed a significant ($P \leq 0.05$) effect of soaking and fermentation time on starch content of maize dough. Multiple comparison test (LSD) [Table 18] suggested

Table 17 Analysis of Variance Summary Table For Starch Content of Maize Dough

Source of Variation	Sum of Squares	d.f.	Mean Squares	F - ratio
Main Effects	728.779	9	80.975	40.513*
Replicate	1.806	1	1.806	0.904
Soaking	212.797	2	106.399	53.233*
Moisture	9.441	2	4.720	2.362
Fermentation	504.734	4	126.183	63.132*
2 - Factor Interactions	64.224	20	3.211	1.607
Soaking x Moisture	17.870	4	4.467	2.235
Soaking x Fermentation	23.283	8	2.910	1.456
Moisture x Fermentation	23.071	8	2.884	1.443
Residual	119.926	60		
Total (CORR.)	912.926	89		

* Significant at $P \leq 0.05$

that starch content of dough at all the levels of soaking (0, 24 and 48hr) and fermentation (0, 6, 24, 48 and 72 hr) were significantly different.

Stepwise multiple regression analysis was used to establish an equation to relate the response to the significant factors from each analysis of variance.

Table 18 Multiple Range Analysis (LSD) of Means of Starch Content

Soaking Time	Mean	Homogeneous Groups	Fermentation Time	Mean	Homogeneous Groups
0	64.77	C	0	69.82	A
24	66.71	B	6	68.54	B
48	68.54	A	24	66.76	C
			48	65.01	D
			72	63.22	E

The regression equation

$$Z = 67.7555 - 0.129X_1 + 0.0005X_1^2 + 0.085X_2$$

where X_1 = Fermentation time and

X_2 = Soaking time

was obtained. There was absence of auto correlation as indicated by the non-significant Durbin - Watson statistics (Durb Wat = 1.012). 88.8% of the variation in starch content of maize dough can be explained by soaking and fermentation time. Fermentation time accounted for 60.9% of the variation in starch content and soaking time 27.9%.

Three dimensional surface graph (Figure 20) prepared from the regression equation shows the trend of the variables studied. Starch content of dough

Fig. 20 Response of maize dough: Effects of soaking and Fermentation on starch content of maize dough.

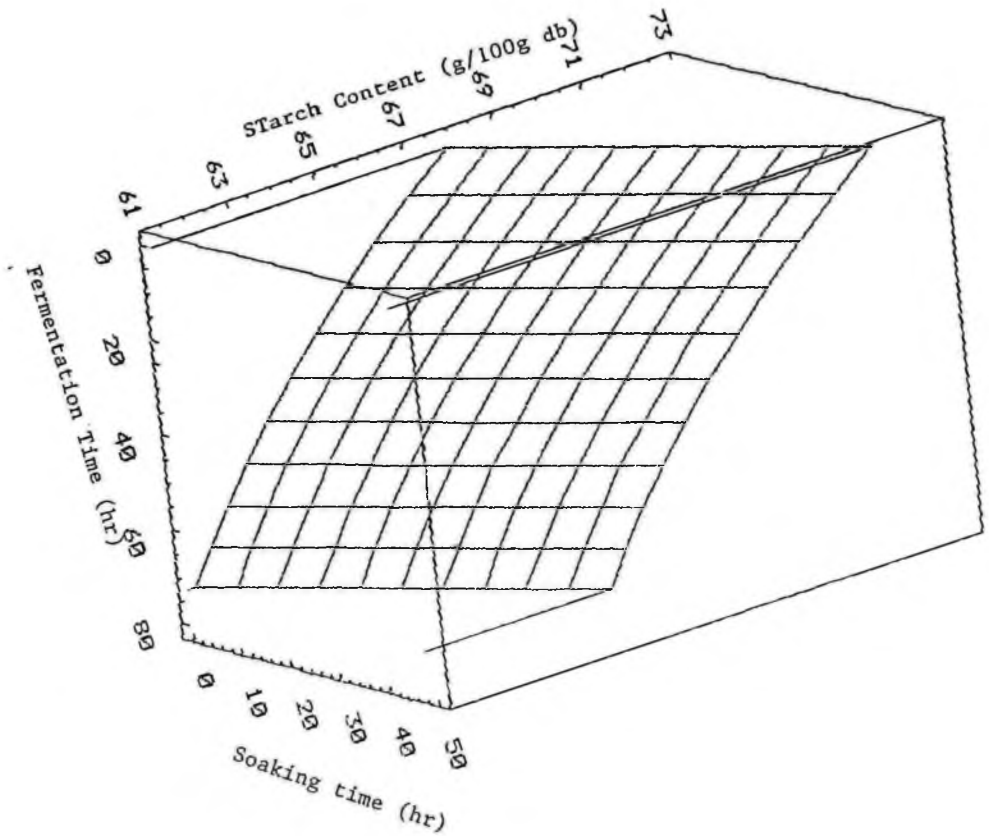
Regression equation:

$$Z = 67.755 - 0.129X_1 + 0.0005X_1^2 + 0.085X_2$$

$R^2 = 88.81\%$

X_1 = Fermentation time (hr)

X_2 = Soaking time (hr)


STarch Content (g/100g db)
61
63
65
67
69
71
73
Fermentation Time (hr)
0
20
40
60
80
Soaking time (hr)
0
10
20
30
40
50

decreased in a curvilinear manner with increase in fermentation time. A linear increase in starch content with increase in soaking time was also observed.

4.5.1.4 Damaged Starch

Table 16 shows that damaged starch content of meal prepared from steeped grain is low. Dry-milling leads to increase in damaged starch. Steeping helps to reduce the proportion of damaged starch in maize meal. It caused a very significant reduction in damaged starch from 5.1% in dry-milled maize flour to 0.56% in 48 hours - soaked and milled maize meal, a decrease of 89%. Vivas *et. al.*, (1987) reported similar findings in dry-milled and wet-milled sorghum and maize meals. The difference in damaged starch content between the dry-milled maize flour and wet-milled maize meals could be explained in terms of the texture of the grains and the efficiency of the milling equipment. Resistance to fracturing and shear will be higher in the dry grain system. Starch granules may fracture along many planes. In the soaked grain system, the particles may become pliable and therefore not fracture, but cell separation may occur.

4.5.1.5 Soluble Sugars

Table 16 indicates that soluble sugars content of steeped maize is low. Steeping seems to contribute to reduction in soluble sugars. Soluble sugars content of dry maize decreased from 6.12 g/100g db to 4.96 g/100g db after 24 hours of steeping and then to 3.62 g/100g db after 48 hours of steeping. This corresponds to a decrease of 23.4% and 69.1% of the original amount of soluble sugars present in the grains. The losses in soluble sugars are due to sugars which leach from the grains and are subsequently metabolized by enzymes or microorganisms.

The bulk of soluble sugars in maize dough is utilized during fermentation. A general decrease in soluble sugars as fermentation time increases is observed (Figure 21). These sugars are metabolised by fermentative microorganisms leading to production of organic acids, alcohol and carbon dioxide. Dry milling of maize results in increase in soluble sugars content of dough at the initial stages of fermentation.

It appears that soluble sugars content of maize dough during fermentation is affected by initial moisture content of the system (Figure 22). Analysis of variance of the data (Table 19) indicated that initial moisture, soaking and fermentation time have significant ($P \leq 0.05$) influence on soluble sugars of dough. This implies that a change in any of these factors can affect the soluble sugars content of maize dough.

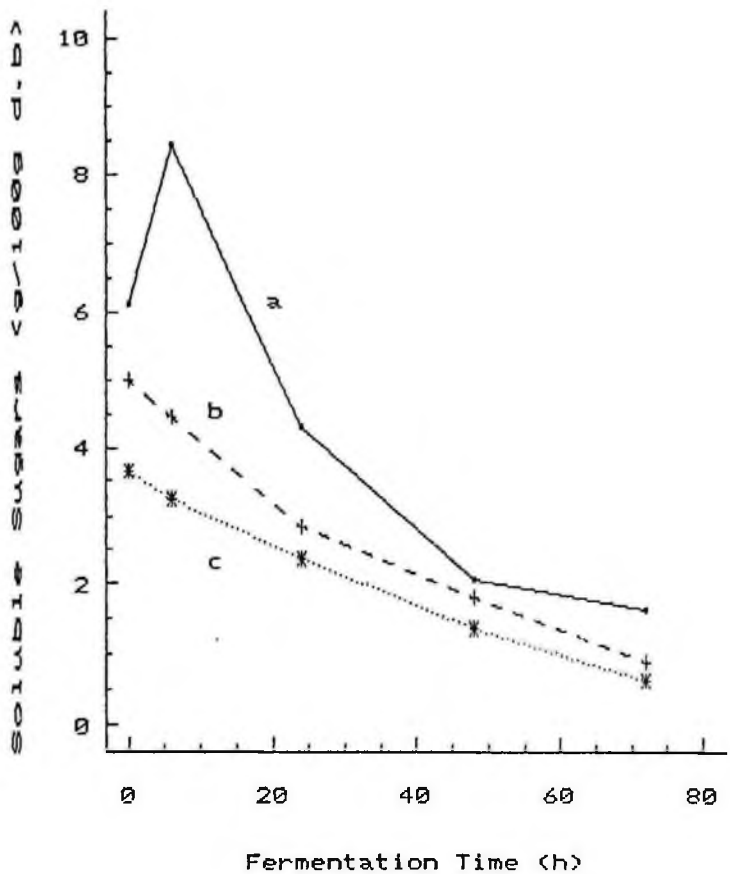
By means of multiple range analysis (LSD) (Table 20) it was established that soluble sugars content at each level of soaking time (0, 24, 48hr), initial

Fig. 21 Effect of Soaking and Fermentation on soluble sugars content of Maize dough.

a = dry-milled maize

b = 24hr wet-milled maize

c = 48hr wet-milled maize



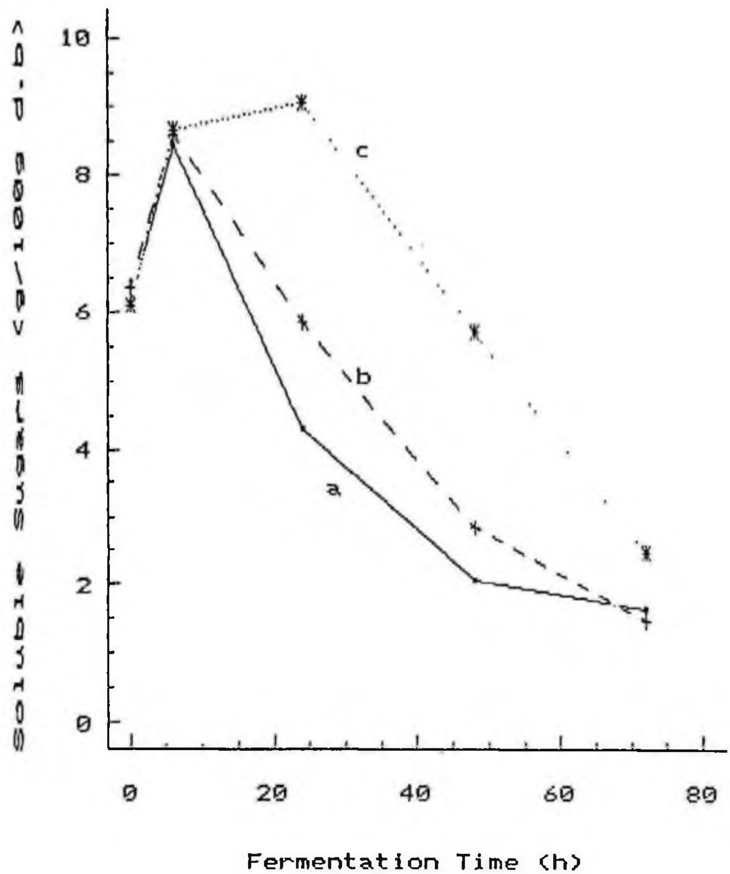
Soluble Sugars (g/100g d.b)
10
8
6
4
2
0
a
b
c
0
20
40
60
80
Fermentation Time (h)

Fig. 22 Effect of Initial Moisture on Soluble sugars content of Fermenting dough made from dry-milled maize.

a = 45% initial moisture

b = 50% initial moisture

c = 55% initial moisture



Soluble Sugars (g/100g d.b)
10
8
6
4
2
0
c
b
a
0
20
40
60
80
Fermentation Time (h)

Table 19 Analysis of Variance Summary Table for Soluble Sugars of Maize Dough

Source of Variation	Sum of Squares	d.f.	Mean Squares	F-ratio
Main Effects	367.418	9	40.824	147.930*
Replicate	0.049	1	0.049	0.179
Soaking	122.491	2	61.245	221.929*
Moisture	9.940	2	4.970	18.009*
Fermentation	234.938	4	58.734	212.830*
2-Factor Interactions	47.997	20	2.400	8.696*
Soaking x Moisture	11.885	4	2.971	10.767*
Soaking x Fermentation	26.053	8	3.257	11.801*
Moisture x Fermentation	10.058	8	1.257	4.556*
Residual	16.588	60	0.276	
Total (CORR.)	431.973	89		

* Significant at P ≤ 0.05

Table 20 Multiple Range Analysis (LSD) of Means of Soluble Sugars

Steeping	Mean	Homogeneous Groups	Initial Moisture	Mean	Homogeneous Groups	Fermentation	Mean	Homogeneous Groups
0	5.161	A	45	3.207	A	0	4.901	B
24	3.209	B	50	3.526	B	6	5.447	A
48	2.378	C	55	4.015	C	24	4.112	C
						48	2.306	D
						72	1.148	E

moisture (45%, 50% and 55%) and fermentation time (0, 6, 24, 48, 72 hr) was significantly ($P \leq 0.05$) different.

A significant ($P \leq 0.05$) interaction between soaking and fermentation time, and initial moisture and fermentation time was also observed. The implication of this finding is that soluble sugars content of maize dough at every fermentation time depends on the soaking time and initial moisture of the dough.

A stepwise multiple regression analysis was used to derive an equation which will establish the relationship between soluble sugars and soaking time, initial moisture and fermentation time. The regression equation obtained

was:

$$Z = -1.571 - 0.076X_1 + 0.1178X_2 + 0.176X_3 + 0.0007X_1X_2 - 0.004X_2X_3$$

where X_1 = fermentation time,

X_2 = soaking time,

X_3 = initial moisture.

Durbin - Watson statistics on the regression equation was not significant ($P \geq 0.05$) indicating the absence of auto-correlation. The equation suggests that soluble sugars content of dough is primarily dependent on soaking and fermentation time. These accounted for 51.7% and 26.7% respectively of the total R^2 of 85.19%. The other significant ($P \leq 0.05$) variables in the regression model are the interaction between fermentation and soaking time, 2.7%, between soaking time and initial moisture, 2.2% and between fermentation and initial moisture, 2.0%.

A graphical representation of the regression model is shown (Figure 23). Soluble sugars content decreased in a linear form with increasing time of soaking and fermentation. More soluble sugars was utilized in fermentation of maize dough prepared from dry-milled maize. As steeping time increased less soluble sugars were utilized during fermentation.

Fig. 23 Effects of Soaking time and Fermentation time on soluble sugars content of maize dough of initial moisture 45%, 50% and 55%.

Regression equation:

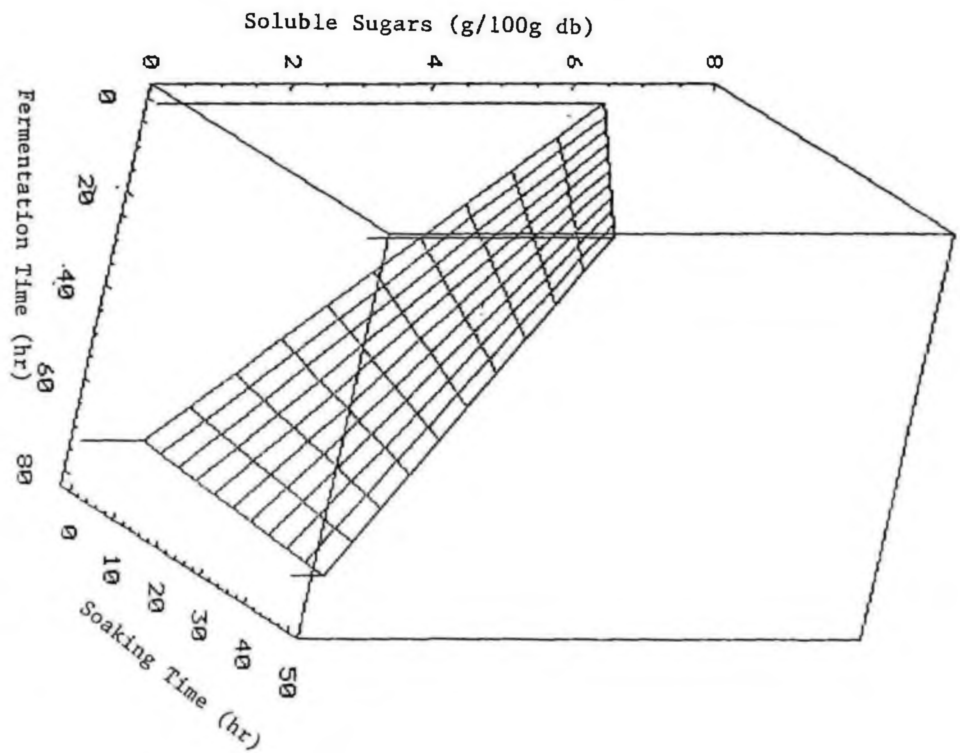
$$Z = -1.571 - 0.076X_1 + 0.1178X_2 + 0.176X_3 + 0.0007X_1X_2 - 0.004X_2X_3$$

$R^2 = 85.19\%$

X_1 = Fermentation Time (hr)

X_2 = Soaking Time (hr)

X_3 = Initial Moisture (%)


Soluble Sugars (g/100g db)
0 2 4 6 8
Fermentation Time (hr)
0 20 40 60 80
Soaking Time (hr)
0 10 20 30 40 50

4.5.1.6 **Total Titratable Acidity**

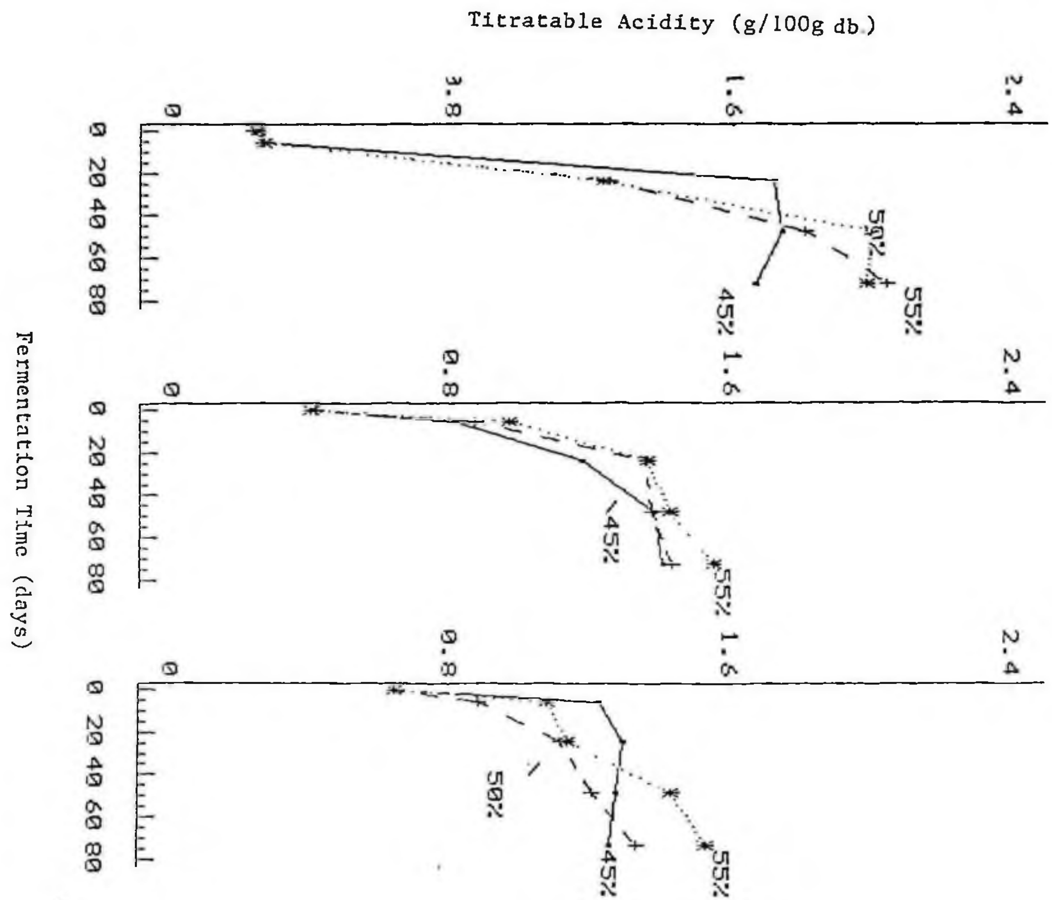
Sourness is an important desirable quality attribute of *komi*. The degree of sourness is a measure of the total titratable acidity of the dough. In traditional processing of *komi* steeping of maize and fermentation of dough are unit operations which contribute to the development of product sourness (flavour and aroma).

Figures 24 (A-C) show that unfermented dough samples made from steeped maize have high dough acidity. Steeping leads to souring of maize prior to milling. The longer the duration of steeping, the greater the quantity of acid produced. In *Komi* manufacture some women steep old/hard maize for 2 - 3 days prior to milling.

Major acid production occurs during fermentation of maize dough. The trend is that dough acidity increases as fermentation time increases. Acid production is delayed in dough samples made from dry-milled maize, however once it commences, there is a high rate of acid production leading to high dough acidity.

Initial moisture content seems to affect titratable acidity of dough during fermentation. High initial moisture appears to favour high dough acidity. As initial moisture is reduced (in the range of 55% to 45%) dough acidity becomes less.

Figs. 24A-C Effects of Fermentation and Initial Moisture on Total Titratable Acidity of maize dough prepared from dry-milled (A), 24hr soaked (B) and 48hr soaked (C) maize.



Titratable Acidity (g/100g db)
Fermentation Time (days)
0 20 40 60 80
0
0.8
1.6
2.4
45%
50%
55%

Table 21 Analysis of Variance Summary Table for Acidity of Maize Dough

Source of Variation	Sum of Squares	d.f.	Mean Squares	F-ratio
Main Effects	18.430	9	2.048	264.867*
Replicate	0.0001	1	0.0001	0.019
Soaking	0.0146	2	0.007	0.944
Moisture	0.053	2	0.026	3.407*
Fermen-tation	18.362	4	4.591	593.772*
2-Factor Interac-tion	4.999	20	0.250	32.330*
Soaking x Moisture	0.104	4	0.026	3.364*
Soaking x Fermenta-tion	4.549	8	0.568	73.547*
Moisture x Fermenta-tion	0.346	8	0.043	5.596
Residual	0.464	60	0.008	
Total (CORR.)	23.892	89		

Analysis of variance of the data (Table 21) showed significant ($P \leq 0.05$) influence of initial moisture and fermentation time and a non-significant ($P \geq 0.05$) influence of soaking time on titratable acidity of dough.

Multiple range analysis (LSD) (Table 22) suggested that dough acidity was significantly ($P \leq 0.05$) different at 0, 6 and 24 hr of fermentation. However dough acidity at 48 hr and 72 hr of fermentation were not significantly different. This finding suggest that fermentation of maize dough beyond 2 days may not be necessary. By the same analysis (LSD), dough acidity at each level of initial moisture (45%, 50%, 55%) were significantly ($P \leq 0.05$) different.

Table 22 Multiple Range Analysis (LSD) of Means of Titratable Acidity

Initial Moisture	Mean	Homogeneous Groups	Fermentation	Mean	Homogeneous Groups
45	1.069	A	0	0.426	A
50	1.083	AB	6	0.734	B
55	1.141	B	24	1.296	C
			48	1.496	D
			72	1.536	D

A significant ($P \leq 0.05$) interaction between initial moisture and fermentation time on dough acidity was also observed (Table 21). Consequently the extent of acid production depends on the amount of water in the dough and the duration of fermentation. Furthermore, there was sufficient evidence that total titratable acidity of dough at every fermentation time is dependent on duration of steeping as indicated by the significant ($P \leq 0.05$) interaction between soaking and fermentation time.

A stepwise multiple regression analysis was performed on the data to relate soaking and fermentation time and initial moisture to dough acidity.

The regression equation:

$$Z = 0.235 + 0.0284X_1 - 0.0004X_1^2 + 0.01X_2 + 0.0004X_1X_3 - 0.0003X_1X_2$$

where X_1 = fermentation time,

X_2 = soaking time and

X_3 = initial moisture

showed statistical significance ($P \leq 0.05$). This indicates that the model (regression equation) is sufficient for predicting dough acidity.

Durbin - Watson statistics of the data was non-significant ($P \leq 0.05$), suggesting the absence of auto-correlation. 86.3% of the variation in dough acidity could be explained by the model. The equation shows a strong dependence of total titratable acidity of dough on the interaction between fermentation time and initial moisture. This accounted for as much as 62.4% of the variation in dough acidity. Other factors in the regression equation which show statistical significance ($P \leq 0.05$) are the quadratic term of fermentation which accounted for 11.6% of the variation in dough acidity. The linear effect of soaking and fermentation time and their interaction accounted for 5.9%, 2.7% and 3.9% respectively of the variation in dough acidity. A three dimensional surface plot (Figure 25) was prepared from the regression model. The effects of soaking and fermentation time were plotted, holding initial moisture content constant.

Figs. 25A - C. Effects of Soaking and Fermentation on Total Titratable Acidity of maize dough of initial moisture 45% (A), 50% (B) and 55% (C).

Regression equation:

$$Z = 0.235 + 0.0284X_1 - 0.0004X_1^2 + 0.01X_2$$

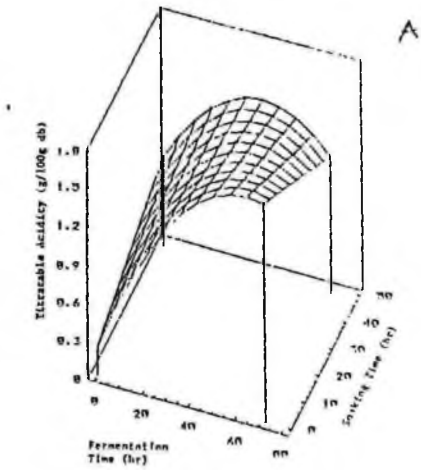
$$+ 0.0004X_1X_3 - 0.0003X_1X_2$$

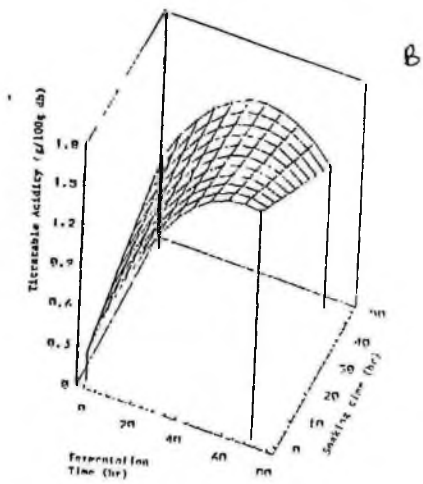
$R^2 = 86.31\%$

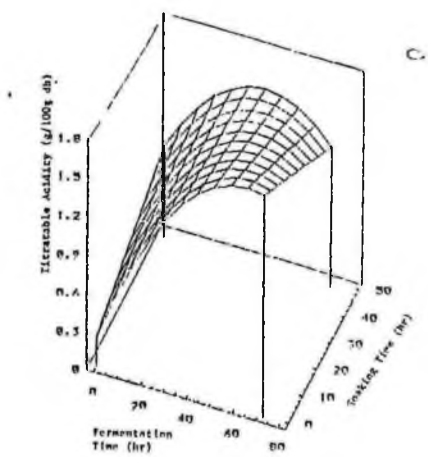
X_1 = Fermentation time (hr)

X_2 = Soaking time (hr)

X_3 = Initial moisture (%)


A
Titratable Acidity (g/100g db)
0
0.3
0.6
0.9
1.2
1.5
1.8
Fermentation Time (hr)
0
20
40
60
80
Soaking Time (hr)
0
10
20
30
40
50


B
Titratable Acidity (g/100g db)
0
0.3
0.6
0.9
1.2
1.5
1.8
Fermentation Time (hr)
0
20
40
60
80
Soaking time (hr)
0
10
20
30
40
50


C
Titratable Acidity (g/100g db)
0
0.3
0.6
0.9
1.2
1.5
1.8
Fermentation Time (hr)
0
20
40
60
80
Soaking Time (hr)
0
10
20
30
40
50

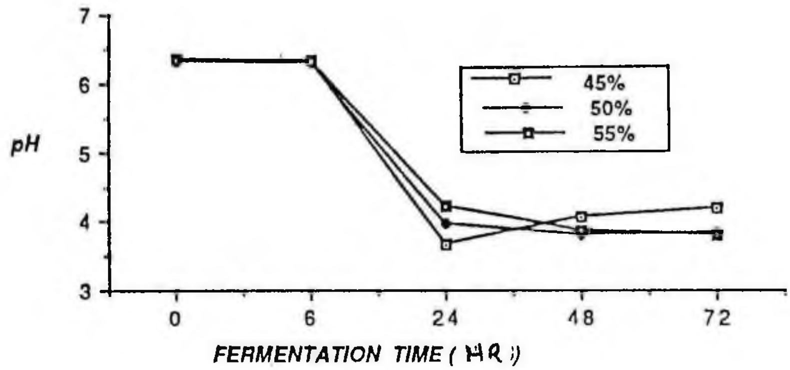
The shape of the plot suggests that dough acidity increases in a curvilinear form with increasing fermentation time. This suggests that prolonged fermentation could be detrimental to acid production. The effect of prolong fermentation on dough acidity becomes pronounced as soaking time increases. Rate of acid production tends to decrease with increase in fermentation time. This could be due to product inhibition of enzymes or micro-organisms expressed only at high concentration or/and limited substrate (soluble sugars). The optimum conditions of soaking and fermentation time and initial moisture which gave peak dough acidity were determined by partial differentiation of the regression equation. This corresponds to soaking and fermentation time and initial moisture of 17 hours, 31 hours and 55% respectively. The implication of this finding is that the total time of 72 - 144 hours observed in the traditional method of making maize dough, could be reduced to 48 hours by observing the optimum variable conditions.

4.5.1.7 pH

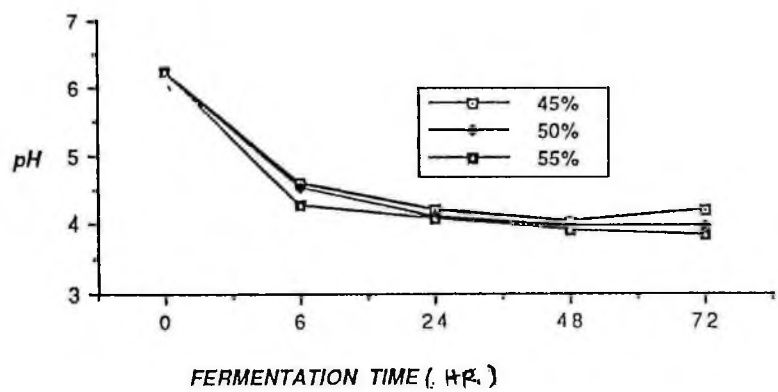
Figures 26 (A-C) show that pH of maize dough decreases during fermentation. Fall in pH was delayed in dough samples prepared from dry-milled maize. Dough pH was also affected by the initial moisture content and soaking time. High initial moisture

Figs. 26A - C. Effects of Fermentation time and Initial moisture content on pH of dough from dry-milled (A), 24hr (B) and 48hr (C) wet-milled maize.

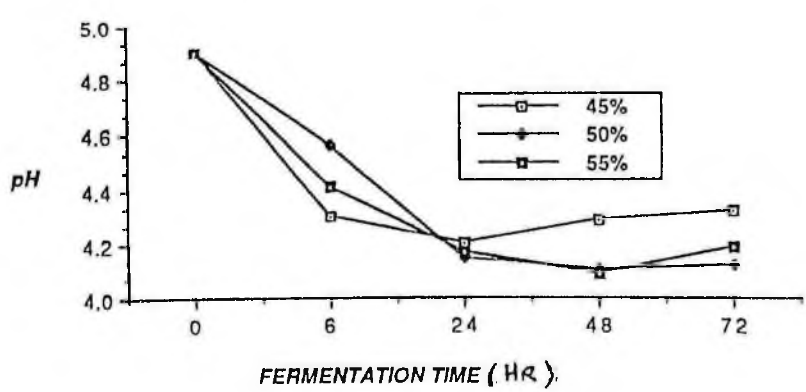
Initial Moisture: 45%, 50% and 55%.



7
6
5
4
3
pH
45%
50%
55%
0
6
24
48
72
FERMENTATION TIME (HR)



7
6
5
4
3
pH
45%
50%
55%
0
6
24
48
72
FERMENTATION TIME (HR.)



5.0
4.8
4.6
4.4
4.2
4.0
pH
45%
50%
55%
0
6
24
48
72
FERMENTATION TIME (HR).

content and dry-milling tends to promote low pH conditions. Statistical analysis (Table 23) indicated a significant (P ≤ 0.05) influence of soaking time, initial moisture and fermentation time on dough pH. Also observed is a significant (p ≤ 0.05) interaction between initial moisture and fermentation time.

Table 23 Analysis of Variance Summary Table for pH of Maize Dough

Source of variation	Sum of Squares	d.f	Mean Squares	F-ratio
MAIN EFFECTS	52.398	9	5.822	927.052*
Replicate	0.001	1	0.001	920.229
Soaking	4.464	2	2.232	355.417*
Moisture	0.077	2	0.039	6.155*
Fermentation	47.855	4	11.964	1000.000*
2-FACTOR INTERACTIONS	19.344	20	0.967	154.013*
Soaking x Moisture	0.061	4	0.015	2.419
Soaking x fermentation	18.948	8	2.368	377.149*
Moisture x fermentation	0.335	8	0.042	6.673*
RESIDUAL	0.377	60	0.006	
TOTAL	72.119	89		

* Significant at p ≤ 0.05

Multiple range analysis (Table 24) showed that pH of dough at each fermentation (0, 6, 24, 48, 72 hr) and soaking (0, 24, 48 hr) time was significantly (P ≤ 0.05) different. It also indicated a non-significant

(P ≥ 0.05) difference in effect due to 50% and 55% initial moisture on dough pH. It is apparent from above that pH of maize dough can be explained by more than one factor.

Table 24 Multiple Range Analysis (LSD) of Means of pH

Soaking	Mean	Homoge-neous Groups	Initial Mois-ture	Mean	Homoge-neous Groups	Fermentation	Mean	Homoge-neous Groups
0	4.898	A	45	4.643	B	0	5.826	D
24	4.550	B	50	4.585	A	6	5.062	C
48	4.358	C	55	4.578	A	24	4.057	AB
						48	4.005	A
						72	4.06	B

A stepwise multiple regression analysis was therefore used to establish the relationship between dough pH and independent factors such as initial moisture, soaking and fermentation time. The model obtained is

$$Z = 6.347 - 0.091X_1 + 0.0008X_1^2 - 0.0294X_2 + 0.0006X_1X_2$$

Where X_1 = fermentation time

X_2 = soaking time

Soaking and fermentation time and their interaction could explain 80.1% of the variation in pH of dough. Fermentation time was significant ($P \leq 0.05$) accounting for 61.4% of the variation. Interaction between the linear components of soaking and fermentation time and the effect of linear term of soaking time accounted for 12.89% and 5.83% respectively. A graphical representation of the regression equation is shown (Figure 27). The plot shows that steeping leads to decrease in the pH of unfermented dough. As fermentation proceeds, the effect of steeping on pH of dough was reversed. Dough pH decreased in a curvilinear manner as fermentation time increased. The optimum conditions of soaking time, initial moisture and fermentation time corresponding to the minimum dough pH are 21 hours, 55% and 49 hours respectively.

4.5.1.8 Pasting Temperature

Figures 28 (A-C) show the effect of fermentation on pasting temperature of slurry of maize dough. Pasting temperature increases at the initial stages of fermentation, reaches a peak and then decreases as fermentation is prolonged. Anim (1991) reported of similar findings in the fermentation of maize dough. For most dough systems the peak of the curve was attained after 24 hours of fermentation. Wet-milling of maize leads to reduction in pasting temperature of dough during fermentation.

Variations in the pasting temperature curves due to initial moisture is also observed. The trend is haphazard, except in dough systems prepared from dry-milled maize. These showed a consistent rise in pasting temperature with increasing initial moisture.

Fig. 27. Effects of Soaking and Fermentation on pH of maize dough.

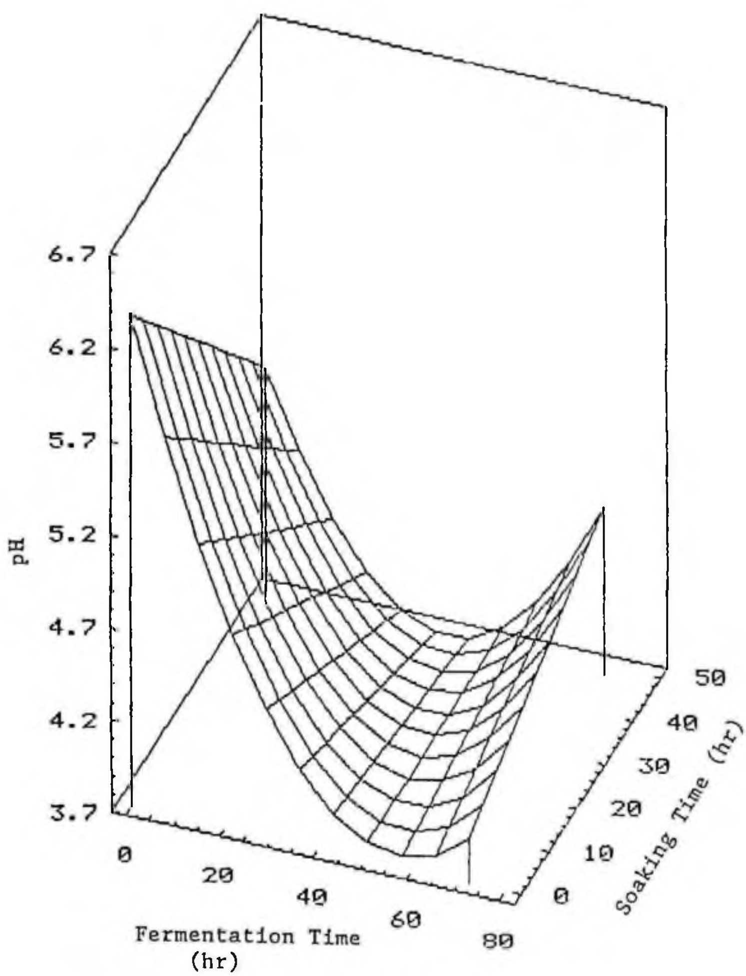
Regression equation:

$$Z = 6.347 - 0.091X_1 + 0.0008X_1^2 - 0.0294X_2 + 0.0006X_1X_2$$

$R^2 = 80.08\%$

X_1 = Fermentation time (hr)

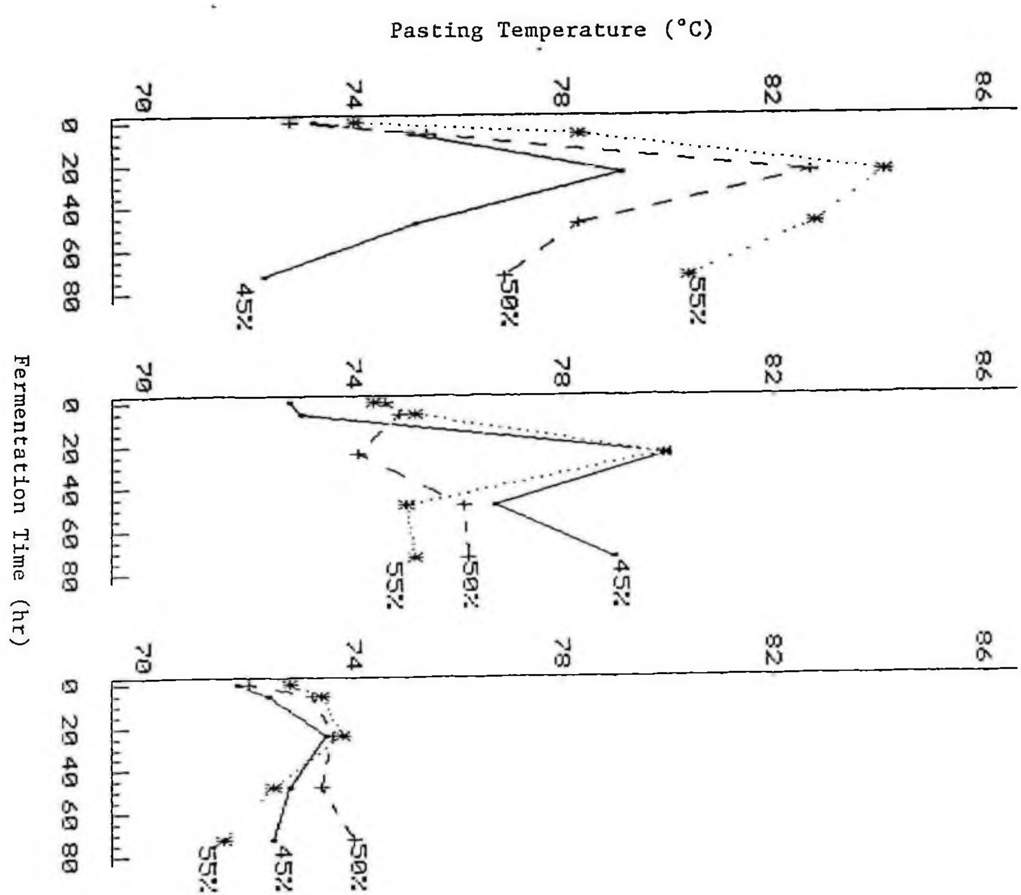
X_2 = Soaking time (hr)



6.7
6.2
5.7
5.2
4.7
4.2
3.7
pH
0
20
40
60
80
Fermentation Time (hr)
0
10
20
30
40
50
Soaking Time (hr)

Fig. 28A - C. Effects of Fermentation and Initial moisture on Pasting Temperature of slurry of dough prepared from dry-milled (A), 24hr (B) and 48hr (C) wet-milled maize.

Initial moisture: 45%, 50% and 55%.



Pasting Temperature (°C)
70
74
78
82
86
Fermentation Time (hr)
0 20 40 60 80
45%
50%
55%

Statistical analysis of the data showed (Table 25) that soaking time, and fermentation time had a significant ($P \leq 0.05$) effect on the pasting temperature of slurry of dough. These changes can be attributed to a possible change in the internal structure of the starch granules caused by the treatment conditions.

Table 25 Analysis of Variance Summary Table for Pasting Temperature of Cooked Dough

Source of Variation	df	Sum of Squares	Mean Squares	F-Value
MAIN EFFECTS	8	284.118	35.515	8.123*
Fermentation	4	108.587	27.147	6.209*
Initial Moisture	2	19.481	9.741	2.228
Soaking	2	156.049	78.025	17.846*
Residual	36	157.394	4.372	
TOTAL (CORR.)	44	441.512		

* Significant at $p \leq 0.05$

4.5.1.9 Brabender Cooked Paste Viscosity

The texture of *Komi* is an important quality index. In the traditional processing of *Komi*, a slurry of dough is cooked to cause starch gelatinization leading to the formation of thick glutinous paste. This acts as a binding agent to raw dough in the preparation of *aflata*. The consistency of the cooked dough plays a very important role in achieving the desired product texture. Fermentation of maize dough was identified (in the survey) as primarily responsible for improving the consistency of the cooked dough.

This section examines the changes in Brabender cooked paste characteristics of maize dough systems during solid-state fermentation. It also examines the extent to which it is affected by pre-fermentation treatment conditions of soaking time and initial moisture content of the dough. The data on Brabender cooked paste viscosity is presented in Table 26.

Figures 29 (A-C) are amylograph curves of samples of dough having 50% initial moisture. A, B and C correspond to dry-milled, 24 hours and 48 hours wet-milled maize respectively. Identical amylographs were obtained for 45% and 55% initial moisture dough samples. The general observation is that amylograph viscosity tends to increase with increasing time of fermentation. The trend of increase in viscosity during fermentation seemed to depend on the prefermentation treatment conditions of the dough. Wet-milling of maize leads to progressive increase in cooked paste viscosity during fermentation. Dry-milling of maize causes a reduction in cooked paste viscosity of dough at the initial stages of fermentation, followed by rapid increase at the later stages of the process. The minimum viscosity was always attained within 24 hours of fermentation, and depended on initial moisture of dough (Table 26).

Figs. 29A - C. Effect of Fermentation on Brabender cooked paste Viscosity of slurry of dough prepared from dry-milled (A), 24hr (B) and 48hr (C) wet-milled maize.

Fermentation condition:

a = 0 hr

b = 6 hr

c = 24 hr

d = 48 hr

e = 72 hr

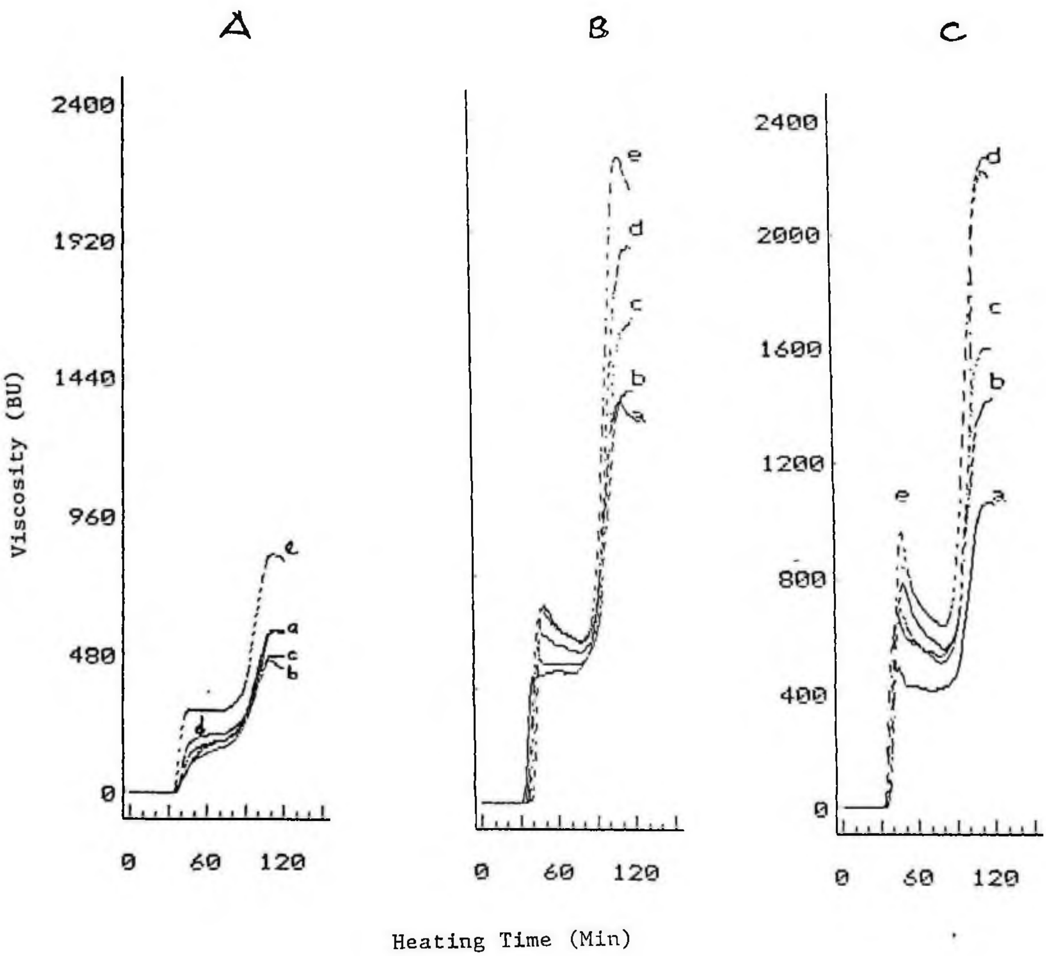

A
B
C
Viscosity (BU)
2400
1920
1440
960
480
0
2000
1600
1200
800
400
0
60
120
a
b
c
d
e
Heating Time (Min)

Table 26 Effects of Soaking Time, Fermentation and Initial Moisture on the Pasting Properties of Maize Dough

Soaking Time (hr)	Initial Moisture of Dough (%)	Fermentation Time (hr)	Pasting Temp. (°C)	VISCOSITY (Brabender Unit)				
				Peak	95°C	95°Hold	50°C	50°Hold
		0	73.2		90	190	505	570
		6	75.1		80	165	445	450
	45	24	79.1		135	195	460	480
		48	75.2		170	215	530	560
		72	72.3	-	285	295	780	815
		0	72.8		110	200	540	570
		6	75.4		70	150	385	400
0	50	24	82.7		85	155	420	430
		48	78.3		250	270	700	770
		72	76.9	-	330	370	705	645
		0	74.0		100	185	490	525
		6	78.3		90	170	490	495
	55	24	84.1		85	150	375	380
		48	82.8		140	180	540	540
		72	80.4	-	170	190	590	590
		0	72.8	470	470	485	1260	1310
		6	73.0	500	520	500	1320	1410
	45	24	80.0	580	580	610	1400	1520
		48	76.7	635	630	530	1500	1640
		72	79.0	670	665	540	1950	2020
		0	74.6	430	425	450	1170	1200
		6	74.9	535	525	495	1320	1470
24	50	24	74.1	590	590	530	1500	1650
		48	76.1	610	610	525	1560	1790
		72	76.2	720	720	695	2230	2140
		0	74.4	460	460	460	1280	1350
		6	75.2	570	510	490	1270	1440
	55	24	79.9	600	600	535	1540	1690
		48	75.0	680	680	570	1700	1940
		72	75.2	695	670	570	2210	2150
		0	71.8	495	440	400	950	1035
		6	72.4	620	580	500	1220	1380
	45	24	73.5	745	735	605	1600	1730
		48	72.8	790	750	625	2310	1850
		72	72.5	875	840	685	2330	1960
		0	72.0	490	450	400	990	1090
		6	73.2	670	640	535	1270	1420
48	50	24	73.6	800	795	590	1520	1755
		48	73.4	860	955	650	1950	2000
		72	74.0	895	885	680	2270	2090
		0	72.8	490	465	420	1000	1050
		6	73.4	645	610	500	1370	1495
	55	24	73.8	695	690	515	1450	1600
		48	72.5	780	775	560	2150	2270
		72	71.5	960	960	640	2010	2190

The changes in amylograph viscosity during fermentation could be explained in terms of the concentration and physicochemical properties of starch and its interactions with other compounds in the food. Amylograph viscosity maximum is determined primarily by the concentration and physicochemical properties of starch (Sebecic, 1989) It is related to starch concentration and physicochemical characteristics by the function

$$MV = a\sqrt{c}$$

where c is the starch concentration and a is a numerical representation of the physicochemical property of starch in the dough/meal under conditions of amylographic determination (Balint and Momirovic - Culjat, 1976). Since the concentration of starch decreased during fermentation the expectation was that amylograph maximum viscosity should have decreased. That it increased suggest a non-corresponding increase in the value of a, thus indicating a change in the physicochemical properties of starch. This phenomenon referred to as annealing is attributed to a change in the internal structure of the starch granule (Gough and Pybus, 1971). The fact that amylograph maximum viscosity kept changing as fermentation time increased suggests that annealing is not instantaneous but rather a process.

Steeping contributes to increase in amylograph viscosity. It is observed that cooked maize dough prepared from dry-milled maize is more stable to retrogradation on cooling. This is of importance in child feeding where energy density and liquid consistency is required (Westby and Gallat, 1991). In searching for flour with stable retrogradation properties on cooling for use in our food systems the answer may lie in dry-milling. This could be due to changes in both the concentration and physico-chemical properties of the starch in the dough system. Table 16 indicates that steeping leads to an apparent increase in starch concentration per unit weight of kernel. There is also evidence of annealing caused by steeping (Gough and Pybus, 1971). These changes (in concentration and internal structure of starch) may be responsible for the increase in amylograph viscosity during steeping.

Statistical analysis of the data (Tables 27 - 31) indicates that soaking and fermentation time had significant ($P \leq 0.05$) influence on amylograph viscosities (peak viscosity, viscosity at 95°C, 95°C Hold, 50°C and 50°C Hold). The practical significance of this is that soaking and fermentation contribute to increase in the consistency of cooked dough and the yield of product, and hence the profit margin.

Table 27 Analysis of variance Summary Table for Peak Viscosity of Cooked Dough

Source of Variation	d.f.	Sum of Squares	Mean Squares	F-Value
Main Effects	8	463799.2	579749	118.878*
Fermentation	4	262996.7	65749.2	13.48*
Initial Moisture	2	1641.1	820.6	0.168
Soaking	2	4373354.4	2186677.2	448.38*
Residual	36	175565.56	4876.82	
Total (CORR.)	44	4812557.8		

* Significant at $p \leq 0.05$

Table 28 Analysis of Variance Summary Table for Viscosity at 95°C of Cooked Dough

Source of Variation	d.f	Sum of Squares	Mean Square	F-Value
Main Effects	8	2967441.1	3709301	97.7*
Fermentation	4	436347.8	109086.9	28.73*
Initial Moisture	2	5563.3	2781.7	0.73
Soaking	2	2525530.0	1262765	332.60*
Residual	36	136678.89	3796.64	
Total (CORR.)	44	3104120.0		

* Significant at $p \leq 0.05$

Table 29 Analysis of Variance Summary Table for Viscosity at 95°Hold of Cooked Dough

Source of Variation	d.f.	Sum of Squares	Mean Square	F-Value
Main Effects	8	1278440	159805	74.41*
Fermentation	4	144291.1	36072.78	16.79*
Initial Moisture	2	10481.1	5240.56	2.44
Soaking	2	1123667.8	561833.89	261.60*
Residual	36	77317.8	2147.72	
Total (CORR.)	44	1355757.8		

* Significant at $p \leq 0.05$

Table 30 Analysis of Variance Summary Table for Viscosity at 50°C of Cooked Dough

Source of Variation	d.f.	Sum of Squares	Mean Square	F-Value
Main Effects	8	14818134	1852266.8	37.80*
Fermentation	4	3584659	896164.7	18.29*
Initial Moisture	2	474	237.2	0.01
Soaking	2	11233001	5616500.6	114.62*
Residual	36	1764030	49000.8	
Total (CORR.)	44	16582164		

* Significant at $P \leq 0.05$

Table 31 Analysis of Variance Summary Table for Viscosity at 50°C Hold of Cooked Dough

Source of Variation	d.f.	Sum of Squares	Mean Square	F-Value
Main Effects	8	14870002	1858750.3	54.45*
Fermenta-tion	4	2591802	647950.6	18.99*
Initial Moisture	2	33510	16755.0	0.49
Soaking	2	12244690	6122345	179.39*
Residual	36	1228627.8	34128.55	
Total (CORR.)	44	16098630		

* Significant at $P \leq 0.05$

4.5.2 To Establish Optimum Conditions For Titratable Acidity, pH and Cooked Paste Viscosity of Maize Dough Using Response Surface Methodology.

4.5.2.1 Total Titratable Acidity

Figures 30 (A-I) show the effect of prefermentation treatment of soaking time, soaking temperature and initial moisture on dough acidity during fermentation. It can be deduced that :

a. Increasing fermentation time leads to increase in dough acidity;

b. Increasing initial moisture leads to increase in dough acidity; and

c. Increasing soaking temperature results in increase in dough acidity.

Acid was produced at a decreasing rate as fermentation time increased. Forty-eight hours seems to be a critical time in the fermentation of maize dough. Up to 48 hours of fermentation there was progressive increase in dough acidity . On further fermentation the direction of change in dough acidity appeared to depend on initial moisture. The low moisture dough samples (all samples of 45% and most of 50% initial moisture dough) showed a decline in dough acidity when fermentation time exceeded 48hr however 55% initial moisture dough showed an increase in titratable acidity throughout the duration of fermentation (72 hr).

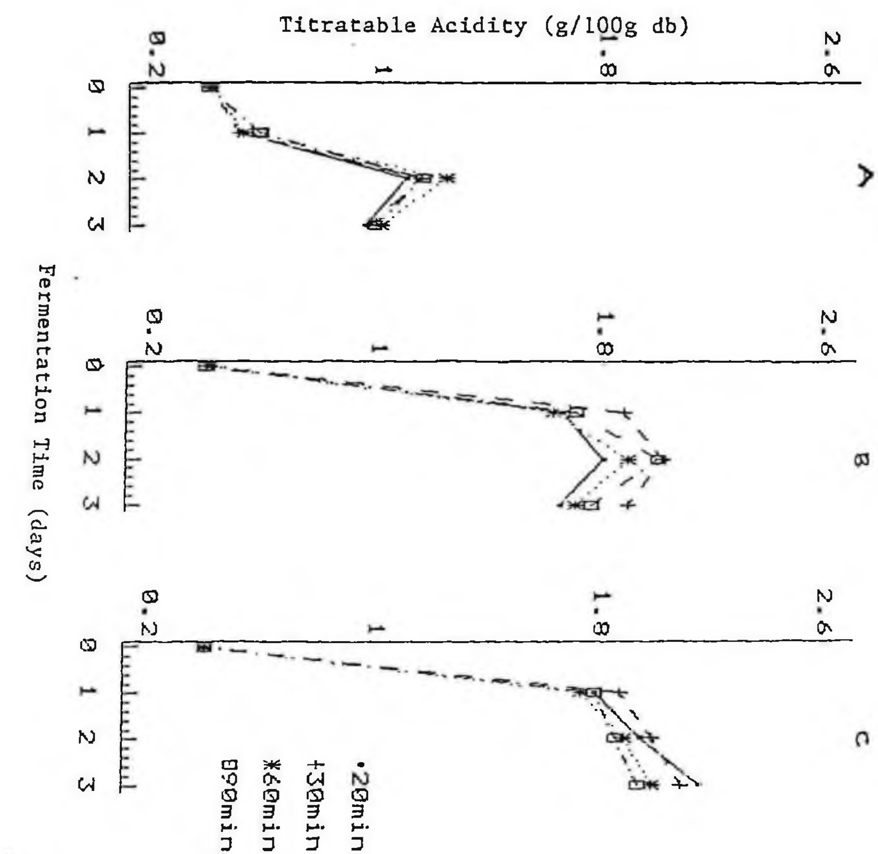
High initial moisture (in the range of 45% to 55%) tends to favour acid production during fermentation

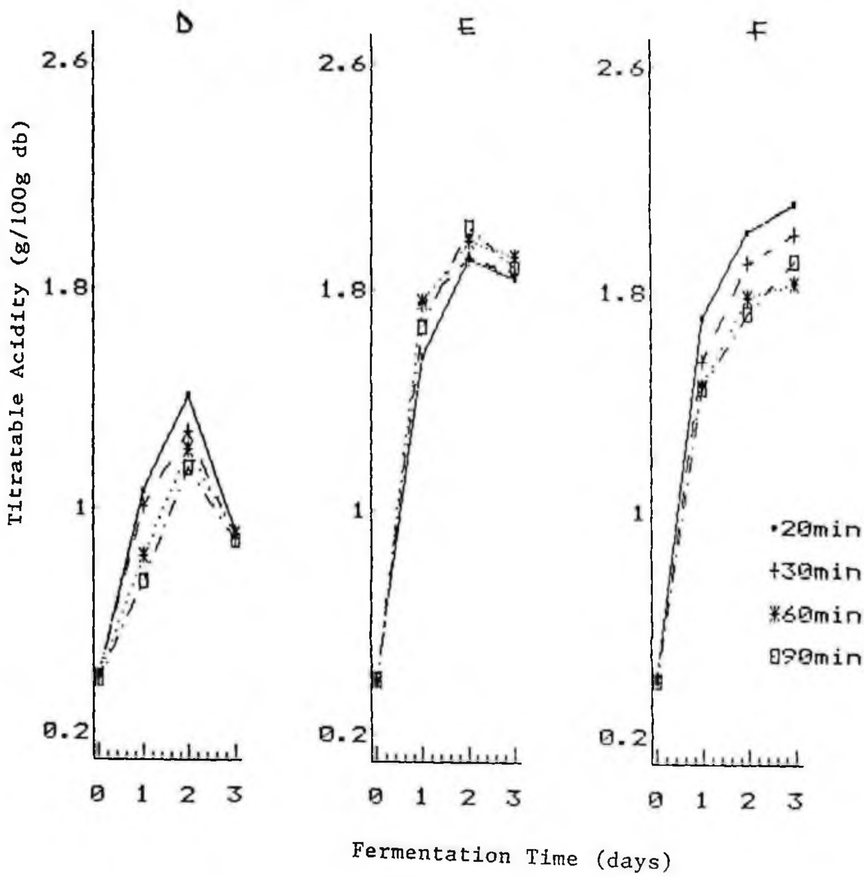
Figs. 30A - I. Effects of Fermentation and Initial moisture on Total Titratable Acidity of dough prepared from maize soaked at 45°C (A-C), 50°C (D-F) and 55°C (G-I).

Prefermentation treatment conditions:

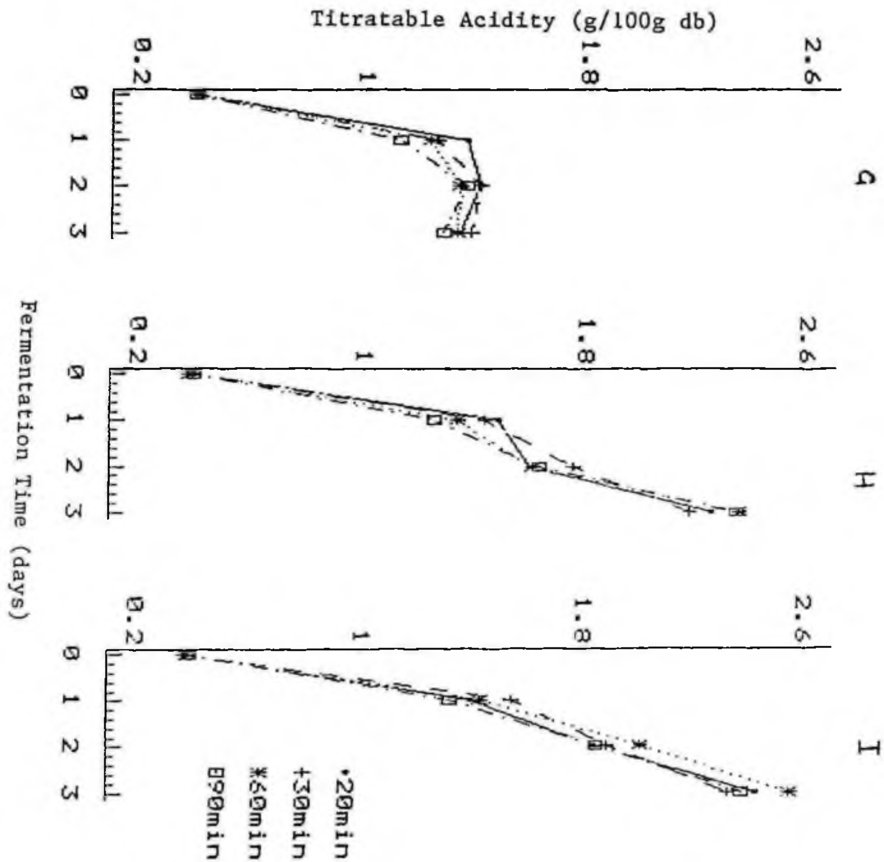
Initial moisture: 45%, 50% and 55%

Soaking time: 20, 30, 60 and 90min.


Titratable Acidity (g/100g db)
Fermentation Time (days)
A
B
C
•20min
+30min
*60min
□90min



D
E
F
2.6
1.8
1
0.2
Titratable Acidity (g/100g db)
0 1 2 3
•20min
+30min
*60min
□90min
Fermentation Time (days)


Titratable Acidity (g/100g db)
0.2
1
1.8
2.6
G
H
I
Fermentation Time (days)
0
1
2
3
•20min
+30min
*60min
□90min

leading to high dough acidity. Plahar and Leung (1982) reported of similar findings in fermentation of maize dough.

The effect of soaking temperature on dough acidity during fermentation is seen in the change in shape of the graph from a curve towards linearity. Increasing soaking temperature (in the range of 45°C to 60°C) favoured acid production.

The graphs also show differences in dough titratable acidity due to differences in soaking time. The trend is haphazard and requires further investigation.

Analysis of variance of the data (Table 32) indicated a significant ($P \leq 0.05$) effect of temperature, initial moisture and soaking time on dough titratable acidity. It also suggested that dough acidity at every fermentation time is dependent an soaking temperature and initial moisture of the system as indicated by the interaction between fermentation time and initial moisture, and between fermentation time and soaking temperature.

By means of Multiple Range analysis (Table 33) it was established that:

a. Titratable acidity of dough having 45%, 50% and 55% initial moisture were significantly ($P \leq 0.05$) different.

b. Total titratable acidity of dough prepared from maize soaked at 45°C and 55°C were not

Table 32 Analysis of Variance Summary Table for Titratable Acidity of Maize Dough

Source of Variation	Sum of Squares	d.f	Mean Squares	F-Ratio
Main Effects	98.158	11	8.923	422.736*
Replicate	0.00004	1	0.00004	0.002
Moisture(M)	20.859	2	10.429	494.091*
Fermentation(F)	76.507	3	25.502	1000.000*
Soaking Temp.(T)	0.498	2	0.249	11.807*
Soaking Time(t)	0.293	3	0.098	4.636*
2 Factor Interaction	11.838	37	0.320	15.158*
M x T	8.518	6	1.420	67.260*
F x T	1.786	6	0.298	14.105*
F x t	0.149	9	0.016	0.787
Residual	5.045	239	0.021	0.787
Total (CORR.)	115.041	289		

* Significant at P ≤ 0.05

Table 33 Multiple Range Analysis (LSD) of Means of Titratable Acidity

Initial Moisture	Mean	Homogeneous Groups	Fermentation	Mean	Homogeneous Groups	Soaking Temperature	Mean	Homogeneous Groups
45	0.888	A	0	0.398	A	45	1.226	A
50	1.426	B	24	1.364	B	55	1.251	A
55	1.487	C	48	1.655	C	60	1.324	B
			72	1.651	C			

significantly ($P \geq 0.05$) different but were significantly ($P \leq 0.05$) different from that of 60°C.

c. Dough titratable acidity of unfermented and 1 day old fermented dough samples were significantly ($P \leq 0.05$) different, but 2 and 3 days fermented dough showed no significant difference.

The importance of these findings are:

a. Fermentation of maize dough beyond 2 days (for the purpose of increasing dough acidity) may not be necessary;

b. Inadequate moisture in the dough could lead to insufficient souring and thereby adversely affect its performance, in terms of taste, flavour and aroma in food products;

c. Acid production (development of sourness) during fermentation can be accelerated by soaking the maize in warm water as against the traditional practice (in Ghana) of steeping maize in water at room temperature.

The practice of soaking maize in warm water is common in Nigeria where in the preparation of *Ogi*, the maize is soaked for only 1 day when warm water is used, compared to 3 days of soaking when cold water (at room temperature) is used.

A stepwise multiple regression analysis was used to derive an equation which relates dough acidity to soaking temperature, soaking time, initial moisture and fermentation time. The equation obtained is:

$$Z = -24.197 + 0.967X_2 - 0.484X_1 - 0.0095X_2^2 - 0.243X_1^2 + 0.032X_1X_2 + 0.006X_3$$

where X_1 = fermentation time,

X_2 = initial moisture,

X_3 = soaking temperature.

Durbin - Watson statistics of the regression equation was non significant ($P \geq 0.05$), indicating the absence of autocorrelation. 89.8% of the variations observed in dough acidity can be explained by the regression equation. The model shows a strong dependence of dough acidity on fermentation time and initial moisture and their interac-tion. As much as 59.2% of the variation in dough acidity can be explained by interaction between fermentation time and initial moisture alone. Fermentation time and initial moisture accounted for 26.9 and 3.3% respectively of the variation in dough acidity. The remaining significant ($P \leq 0.05$) factor in the regression equation is the linear term of soaking temperature which accounted for 0.3% of the variation observed.

Figure 31A is a graphical representation of the regression equation showing the effects of fermentation time and initial moisture at constant soaking temperature. The importance of fermentation time and initial moisture in the development of dough acidity is clearly shown. Dough acidity increases in a curvilinear manner as initial moisture and fermentation time increases. When soaking temperature is increased (in the range of 45°C - 60°C) the height of the response surface plot remains unchanged (Figure 31B & C). Peak titratable acidity (2.17 g/100g) of dough was obtained at the following processing conditions:

Soaking temperature = 60°C

Initial moisture = 55%

Fermentation time = 64.8 hr.

4.5.2.2 Comparison of Traditional and Optimization Processes

More acid was produced in the optimization process (peak value = 2.17 g/100g of dough) than in the traditional process (peak value = 1.73 g/100g of dough). This cannot be considered as an improvement in dough acidity over the traditional process as sensory analysis was not conducted to determine consumer preference. The peak dough acidity of 1.73 g/100g observed in the traditional system corresponded to 17 hours of soaking and 31 hours of fermentation. The same value was achieved in ⅓ - 1½ hours of soaking and

Figs. 31A - C. Effects of Initial moisture and Fermentation time on Total Titratable Acidity of maize dough at soaking temperature 45°C (A), 55°C (B) and 60°C (C).

Regression equation:

$$Z = -24.197 + 0.967X_2 - 0.484X_1 - 0.0095X_2^2 - 0.243X_1^2 + 0.032X_1X_2 + 0.006X_3$$

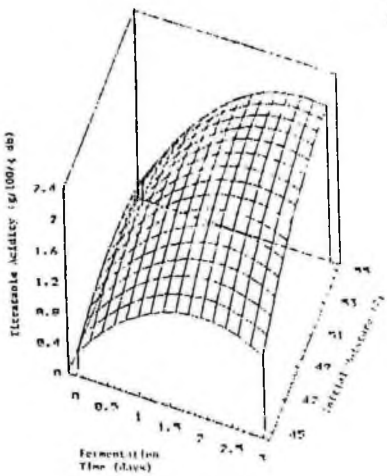
$R^2 = 89.77\%$

X_1 = Fermentation time (days)

X_2 = Initial moisture (%)

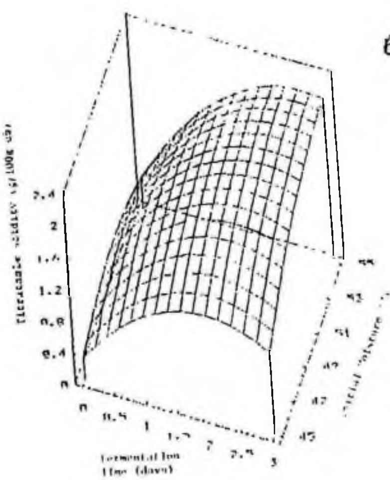
X_3 = Soaking Temperature (°C)

A



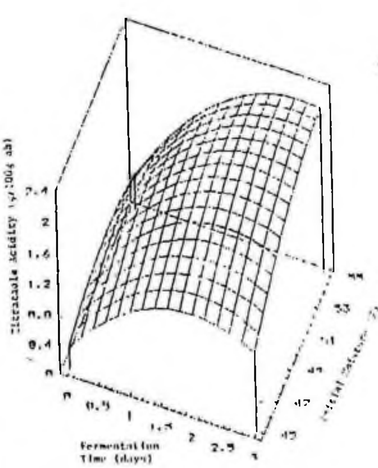
Titratable Acidity (g/100g db)
2.4
2
1.6
1.2
0.8
0.4
0
0
0.5
1
1.5
2
2.5
3
Fermentation Time (days)
45
47
49
51
53
55
Initial Moisture (%)

B



Titratable Acidity (g/100g db)
2.4
2
1.6
1.2
0.8
0.4
0
0
0.5
1
1.5
2
2.5
3
Fermentation Time (days)
45
47
49
51
53
55
Initial Moisture (%)

C



Titratable Acidity (g/100g db)
2.4
2
1.6
1.2
0.8
0.4
0
0
0.5
1
1.5
2
2.5
3
Fermentation Time (days)
45
47
49
51
53
55
Initial Moisture (%)

22.2 hours of fermentation in the optimization process. A minimum of 20 hours is therefore saved when the optimization process is used. This process could therefore be considered an improvement over the traditional process.

It may be possible to reduce further the duration of processing by varying the significant variables in the regression equation.

4.5.2.3 pH

The effects of soaking temperature, soaking time, initial moisture and fermentation time on the pH of dough are summarised in figures 32(A-I). pH of dough decreased during fermentation. In the initial 24 hours of fermentation, pH decreased in all the dough systems. On further fermentation, dough pH either decreased or increased depending on the initial moisture. Dough samples with relatively high initial moisture (55%) were predisposed to further decrease in pH after 24 hours of fermentation.

The effect of soaking temperature on dough pH is seen in the decline in pH as soaking temperature increased.

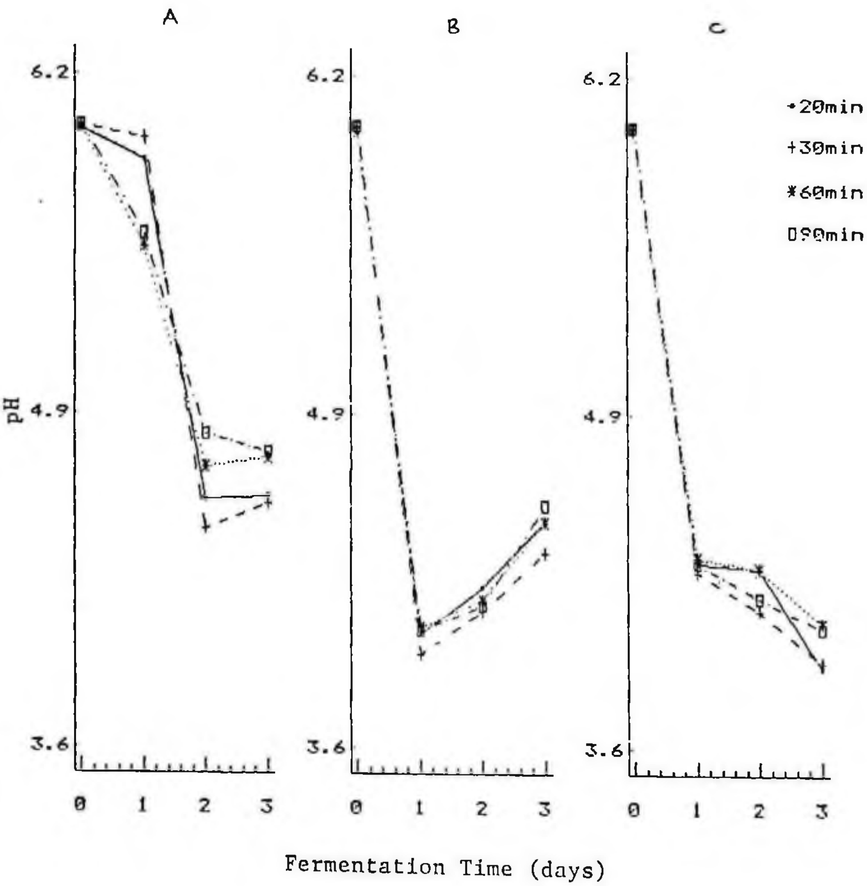
Analysis of variance of the data (Table 34) showed significant ($P \leq 0.05$) effects of fermentation time, initial moisture and soaking temperature on dough pH.

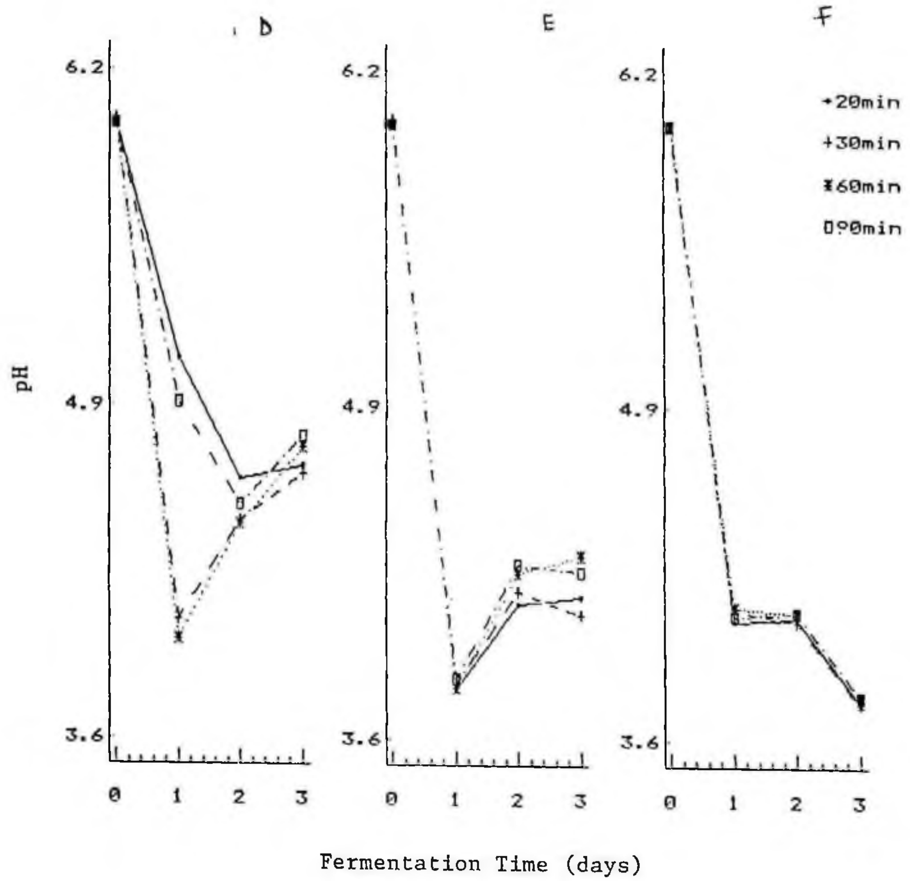
Figs. 32A - I. Effects of Fermentation time, Soaking temperature and Soaking time on pH of maize dough of initial moisture 45%, 50% and 55%.

Prefermentation treatment conditions:

Soaking temperature: 45°, 55° and 60°C

Soaking time: 20, 30, 60 and 90min.


A
B
C
6.2
4.9
3.6
pH
•20min
+30min
*60min
□90min
0
1
2
3
Fermentation Time (days)



D
E
F
6.2
4.9
3.6
pH
0
1
2
3
•20min
+30min
*60min
□90min
Fermentation Time (days)

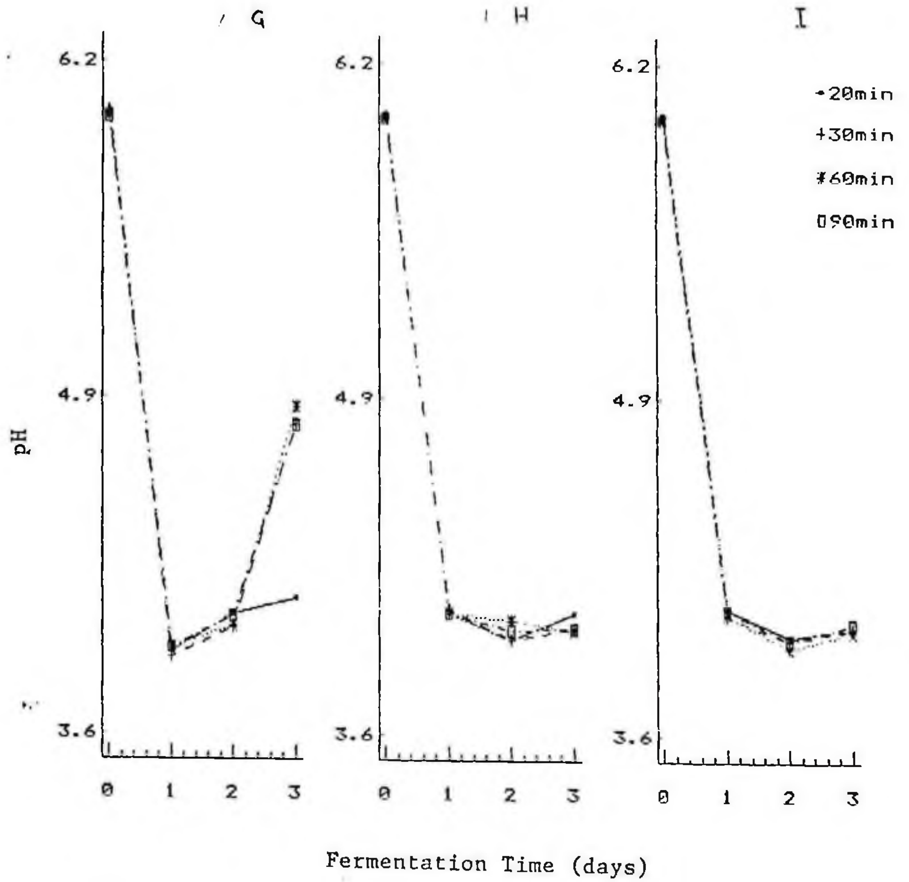

G
H
I
6.2
4.9
3.6
pH
•20min
+30min
*60min
□90min
0
1
2
3
Fermentation Time (days)

Table 34 Analysis of Variance Summary Table pH of Maize Dough

Source of Variation	Sum of Squares	d.f.	Mean Squares	F-ratio
Main Effects	178.819	11	16.256	422.737*
Replicate	0.0001	1	0.0001	0.004
Moisture (M)	9.201	2	4.600	119.633*
Fermenta-tion(F)	165.266	3	55.088	1000.000*
Soaking temp.(T)	4.262	2	2.131	55.416*
Soaking Time(t)	0.089	3	0.029	0.779
2 Factor Interac-tion	11.953	37	0.323	8.401*
M x F	5.787	6	0.964	25.081*
F x T	3.171	6	0.528	13.742*
F x t	0.346	9	0.038	1.000
Residual	9.191	239	0.038	
Total	199.962	287		

Multiple comparison test (Table 35) suggested that:

a. Dough pH at each level of fermentation time (0, 1, 2 and 3 days) is significantly ($P \leq 0.05$) different.

b. Soaking temperatures of 45°C, 55°C and 60°C have significantly different ($P \leq 0.05$) effects on dough pH.

c. The effect on dough pH due to 55% and 50% initial moisture were not significantly different, but were significantly ($P \leq 0.05$) different from 45% initial moisture.

Table 35 Multiple Range Analysis (LSD) of Means of pH

Fermen-tation	Mean	Homoge-neous Groups	Initial Moisture	Mean	Homogeneous Groups	Soaking Tempera-ture	Mean	Homoge-neous Groups
0	5.988	D	45	4.936	B	45	4.848	C
24	4.351	C	50	4.575	A	55	4.646	B
48	4.125	A	55	4.541	A	60	4.557	A
72	4.271	B						

To predict the relationship that exists between pH of dough and soaking temperature, fermentation time and initial moisture a regression equation was derived using stepwise multiple regression analysis. Durbin-Watson Statistics (Durb Wat = 1.117) of the regression equation,

$$Z = 7.606 - 0.0126X_2 - 0.9787X_1 + 0.446X_1^2 - 0.018X_1X_2 - 0.0195X_3$$

where X_1 = fermentation time

X_2 = initial moisture

X_3 = soaking temperature

was non-significant indicating the absence of auto-correlation. 87.3% of the variation in the pH of maize dough could be explained by the model. A significant interaction between the linear components of fermentation time and initial moisture of dough was observed. This accounted for as much as 55.2% of the variation in pH. Also there was a significant ($P \leq 0.05$) effect due to fermentation time which accounted for 29.9% of the variation in dough pH. Other significant ($P \leq 0.05$) factors in the model were the linear effects of soaking temperature and initial moisture of dough. These accounted for 2.1% and 0.1% respectively of the variations in pH.

Figure 33 is a graphical representation of the regression model corresponding to soaking temperature of 45°C. The importance of fermentation time and initial moisture on dough pH is clearly shown. The pH of dough decreased in a curvilinear form with increase in fermentation time. At each fermentation time, dough pH was dependent on initial moisture. As initial moisture decreases, the fall in pH becomes less.

A plot of fermentation time and initial moisture when the soaking temperature is increased from 45°C to 60°C would increase the depth of the surface plot. However the surface of the plot remains unchanged. This means high soaking temperatures favour low pH conditions during fermentation of maize dough.

The optimum conditions of fermentation time, initial moisture and soaking temperature which produced the minimum pH (pH = 3.87) were 57.6 hours, 55% and 60°C respectively.

A look at the data shows a relatively poor relationship between pH and total titratable acidity in some of the dough samples. This observation could be explained in terms of the interactions between the acids and macro-molecules present in the system. Whilst dough acidity (titration) is a reflection of total protons being contributed by all acids present in the system dough pH measured by the pH meter only

Fig. 33 Effects of Initial moisture and Fermentation time on pH of maize dough at Soaking temperature 45°C.

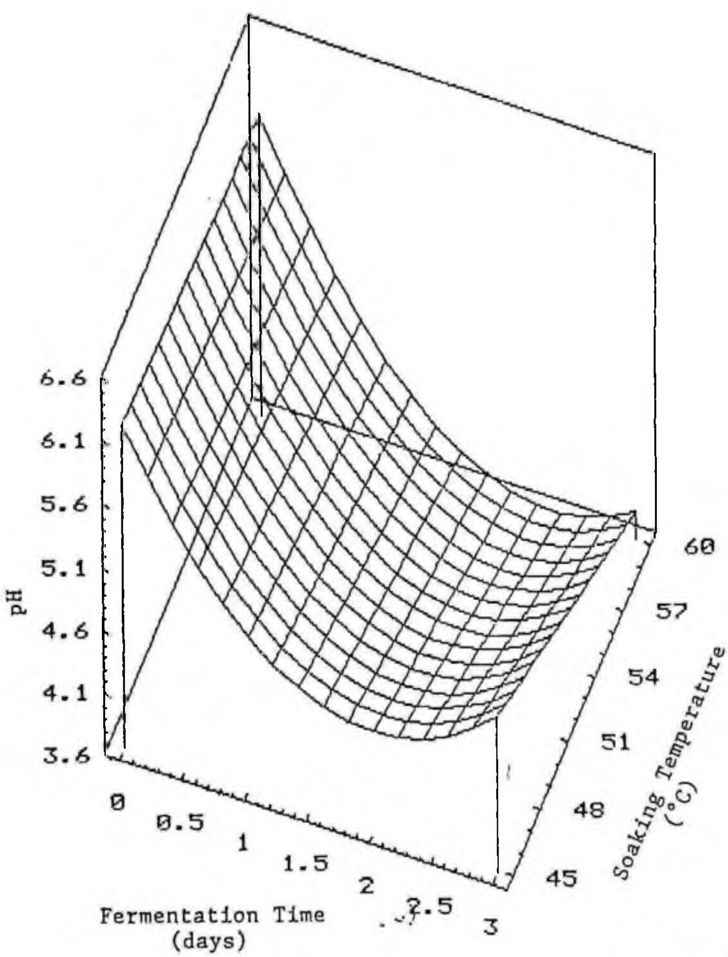
Regression equation:

$$Z = 7.606 - 0.0126X_2 - 0.9787X_1 \; 0.446X_1^2 - 0.018X_1X_2 - 0.0195X_3$$

$R^2 = 87.32\%$

X_1 = Fermentation time (days)

X_2 = Initial moisture (%)


6.6
6.1
5.6
5.1
4.6
4.1
3.6
pH
0
0.5
1
1.5
2
2.5
3
Fermentation Time
(days)
60
57
54
51
48
45
Soaking Temperature
(°C)

indicates the protons present due to the dissociation of the strongest acid. Soluble proteins in the system may also have a buffering effect on the pH change.

4.5.2.4 Viscosity as Determined by Brookfield Viscometer

Figures 34 (A-I) show that viscosity of cooked slurry of dough increases as fermentation time increased. The rate of increase appears to be uniform in all the dough samples. The increase in viscosity of cooked slurry of dough might be due to fermentation initiated changes in the internal structure of the starch granule. This phenomenon has important economic implications to the food processor in that, increase in consistency leads to increase in yield of product and therefore wider profit margin. This is in agreement with findings of the field survey that fermentation increases swelling and viscosity of cooked dough.

Viscosity of cooked dough increased when soaking temperature increased form 45°C to 55°C. Further increase in temperature resulted in a decline in viscosity. For example the mean viscosity of unfermented dough was about 5900, 6200 and 5200 centipoise corresponding to soaking temperatures of 45°C, 55°C and 60°C respectively.

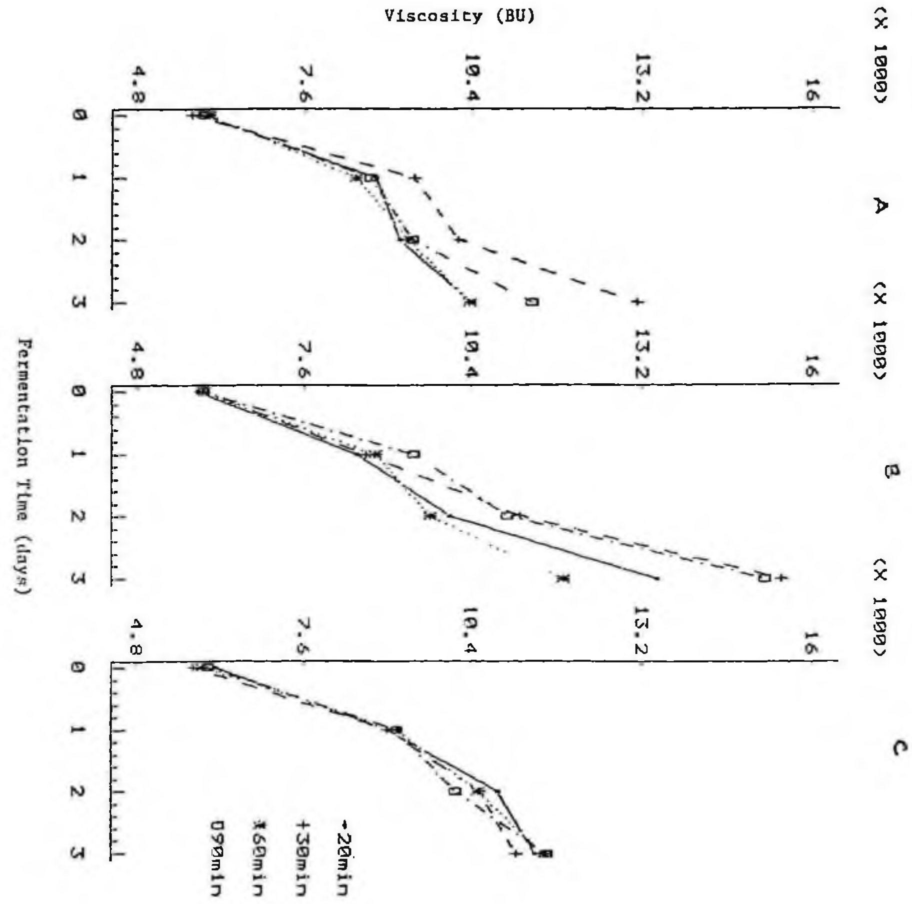
Initial moisture of dough also appeared to affect the viscosity of cooked dough. Viscosity increased when initial moisture was increased from 45% to 50%. Further increase in moisture from 50% to 55% registered

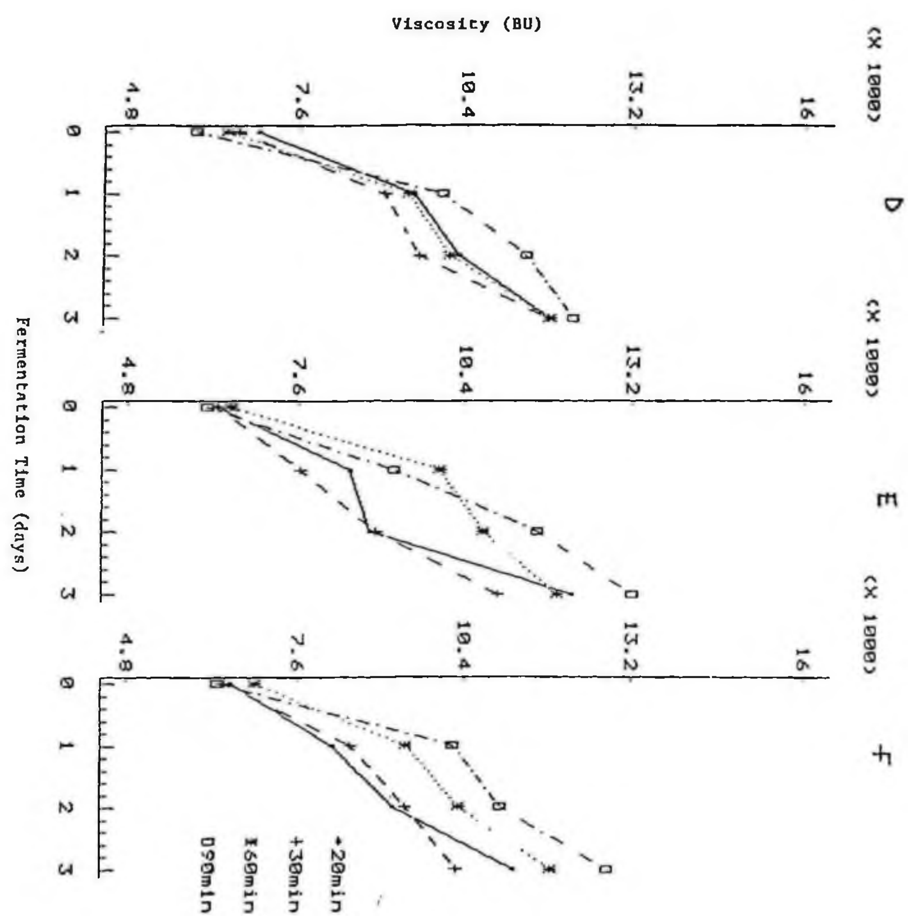
Figs. 34A - I Effect of Fermentation time on Viscosity of cooked slurry of maize dough samples of initial moisture 45% (A), 50% (B) and 55%.

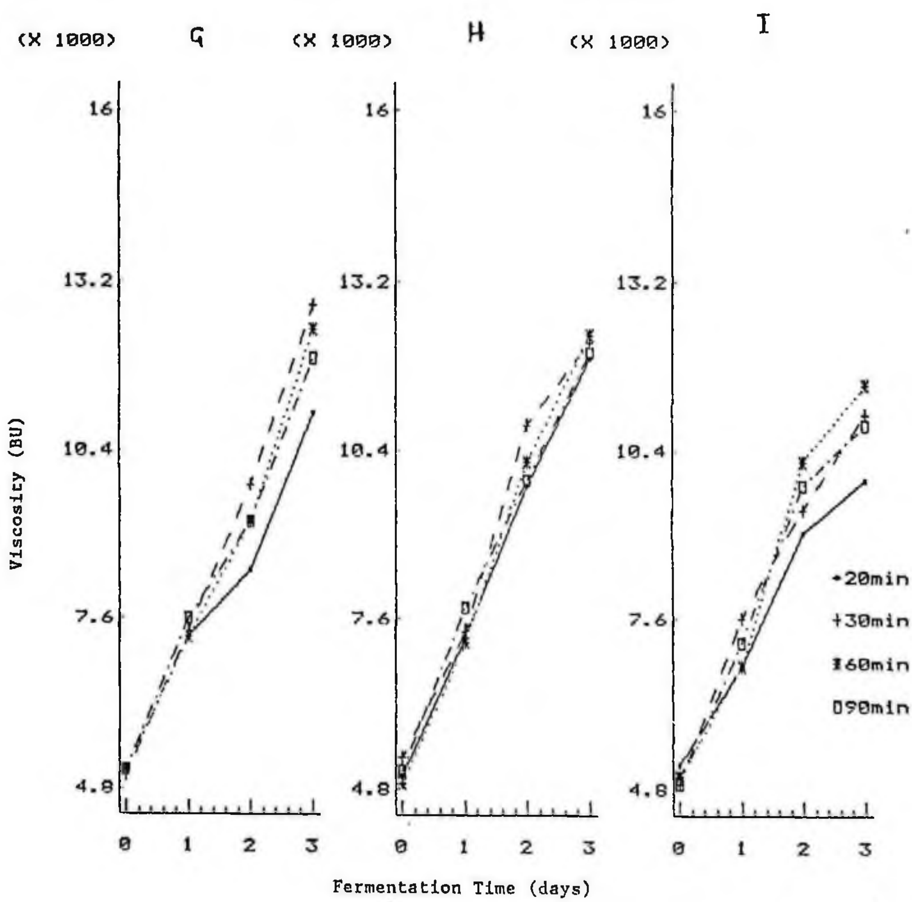
Prefermentation treatment conditions:

Soaking temperature: 45°, 55° and 60°C

Soaking time: 20, 30, 60 and 90min.


Viscosity (BU)
(X 1000)
A
B
C
4.8
7.6
10.4
13.2
16
0
1
2
3
Fermentation Time (days)
20min
30min
60min
90min


Viscosity (BU)
(X 1000)
D
E
F
4.8
7.6
10.4
13.2
16
0
1
2
3
Fermentation Time (days)
•20min
+30min
*60min
□90min



(X 1000)
G
H
I
16
13.2
10.4
7.6
4.8
Viscosity (BU)
0
1
2
3
Fermentation Time (days)
•20min
+30min
*60min
□90min

a decline in viscosity of cooked dough.

Statistical analysis of the data (Table 36) showed significant ($P \leq 0.05$) effects of soaking temperature, soaking time, initial moisture and fermentation time on viscosity of cooked dough. Also a significant ($P \leq 0.05$) interaction between soaking temperature and fermentation time was observed.

By multiple range test (Table 37) it was established that:

a. effect of each level of fermentation (0, 1, 2 and 3 days) on viscosity of cooked dough was significantly ($P \leq 0.05$) different;

b. effect of soaking at 45°C and 55°C was not significantly ($P \geq 0.05$) different, but were different from that of 60°C; and

c. there is significant difference between the effects due to 45% and 55% initial moisture on viscosity.

There is sufficient evidence from the foregoing to show that soaking temperature, soaking time, initial moisture and fermentation time are relevant to viscosity of cooked dough.

A stepwise multiple regression analysis was used to establish an equation to predict viscosity. The regression equation,

$$Z = -26170.01 + 2241.175X_1 + 1311.206X_2 + 5.527X_1X_2 - 182.465X_1^2$$

Table 36 Analysis of Variance Summary Table for Viscosity of Cooked Dough

Source of Variation	Sum of Squares	d.f.	Mean Squares	F-ratio
Main Effects	1.5173E0009	11	1.3794E0008	344.577*
Replicate	2.2931E0006	1	2.2931E0006	4.728
Moisture(M)	8.8793E0006	2	4.4396E0006	11.090*
Fermentation(F)	1.4414E0009	3	4.8047E0008	1000.000*
Soaking Temp.(T)	5.4174E0007	2	2.7087E0007	67.665*
Soaking Time(t)	1.0953E0007	3	3.6510E0006	9.120*
2 Factor Interaction	96907411	37	2619119.2	6.543*
M x F	23018606	6	3836434.3	9.584*
F x T	23116028	6	3852671.3	2.624*
F x t	9427999	9	1047555.4	2.617*
Residual	95674857	239	400313.21	
Total	1.7099E0009	287		

Table 37 Multiple Range Analysis (LSD) of Means of Viscosity

Fermentation	Mean	Homogeneous Groups	Initial Moisture	Mean	Homogeneous Groups	Soaking Temperature	Mean	Homogeneous Groups
0	5788.889	A	45	8946.354	A	45	9317.187	A
24	8455.556	B	50	9265.625	B	55	9369.792	A
48	9974.306	C	55	8885.417	A	60	8410.417	B
72	11911.111							

where X_1 = fermentation time

X_2 = soaking temperature,

was significant ($P \leq 0.05$) indicating that it is sufficient for predicting the response. Durbin-Watson statistics (Durb Wat = 1.124) was not significant ($P \leq 0.05$) suggesting a condition of no autocorrelation. The model shows that almost 87% (R^2 = 86.88%) of the variation in viscosity of cooked dough can be explained by fermentation time and soaking temperature. As much as 82.7% (linear and quadratic effects being 82.2% and 0.5% respectively) of the variation in viscosity is contributed by fermentation alone. Soaking temperature was also significant ($P \leq 0.05$) accounting for 4.2% (quadratic and linear terms being 2.8% and 1.4% respectively) of the variation.

To illustrate the regression equation graphically, the effects of fermentation time and soaking temperature were plotted (Figure 35). It is clear that fermentation time has a profound influence on viscosity of cooked dough. Viscosity of cooked dough increased in a curvilinear form with increase in fermentation time and soaking temperature. The highest increase in viscosity corresponded to soaking temperature of 51°C and fermentation time of 3 days.

Fig. 35 Effects of Fermentation time and Soaking temperature on Viscosity of cooked slurry of maize dough.

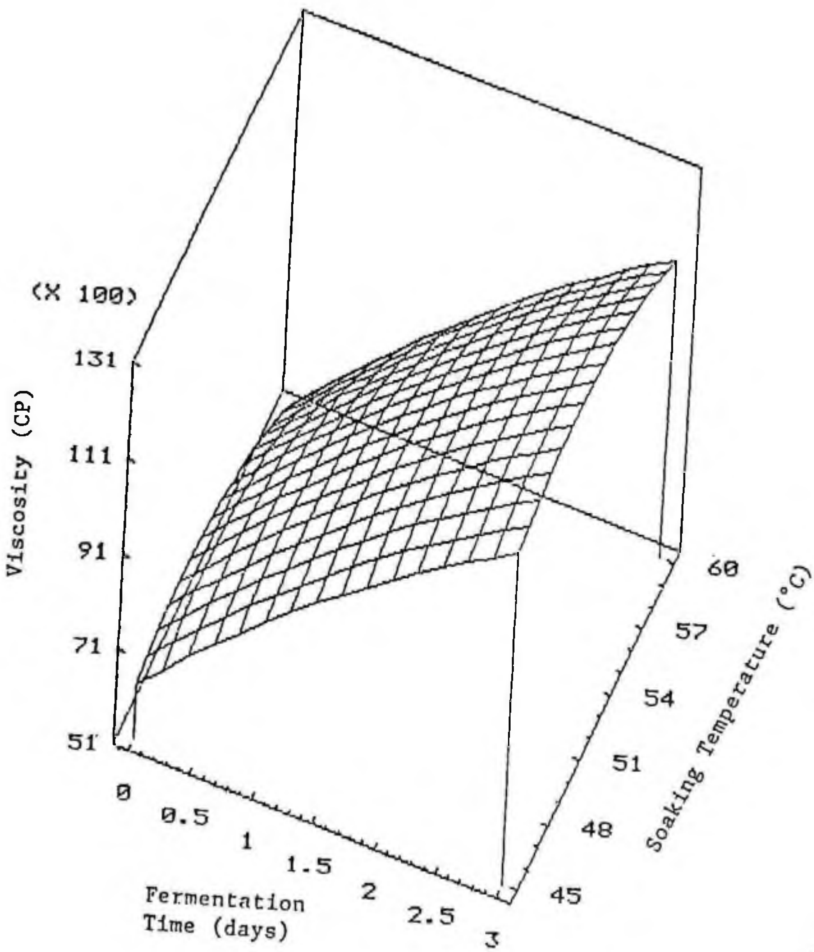
Regression equation:

$$Z = -26170.01 + 2241.175X_1 + 1311.206X_2 + 5.527X_1X_2 - 182.465X_1^2$$

$R^2 = 86.88\%$

X_1 = Fermentation time (days)

X_2 = Soaking Temperature (°C)



(X 100)
131
111
91
71
51
Viscosity (CP)
0
0.5
1
1.5
2
2.5
3
Fermentation Time (days)
45
48
51
54
57
60
Soaking Temperature (°C)

4.6 CONCLUSION

4.6.1 Survey

1. a. The *Komi* industry is a small-scale home-based enterprise contributing to family income. The household also depend heavily on part of the product intended for sale as their source of food.

   b. Females control the industry whilst males play a supportive role. The industry engages essentially adults in their prime of life. As people age they stay away from the business.

   c. Educational level of *komi* processors is generally low. Majority have no formal education, the remaining have education up to the primary or middle school levels. Issues related to technology transfer and adoption should therefore be demonstration oriented.

2. a. The product has high demand. Unsold product is recycled to reduce economic losses. Seasonality affects the demand for the product.

   b. Shrewd marketing policies and strategies, such as the extension of interest free credit facilities to financially handicapped customers, are used to entice and keep customers.

c. Profit margin generally increases with increase in quantity of maize used per batch of *komi*. Medium scale production is characterized by economies of scale while large-scale production appears to have diseconomies of scale.

d. Weaning infants with *komi* is uncommon. When used it is administered in the mashed form or "as is" with soup.

e. The by-product (cooked liquor) of *komi* is believed to possess medicinal properties. It is used as oral rehydration salt and for relieving jaundice.

3. Maize (*Zea mays*) is the predominant raw material used in the manufacture of *komi*, other materials used are corn sheath and salt. The local variety of maize is the most preferred for making *komi*, because of good swellability and texture characteristics.

4. a. The technology of application is traditional involving uncontrolled and unstandardized biotechnological and physical processes that contribute to the development of desired quality attributes such as aroma, flavour and texture. Unit operations identified as critical for good quality *komi* are:

a. cleaning of maize

b. soaking of maize

c. milling of maize

d. moisture content (or firmness) of dough

e. fermentation of dough

f. preparation of glutinous paste

g. preparation of *aflata*

h. packaging and product arrangement in cooking receptacle

i. boiling

The milling operation is the only process that has undergone a revolutionary change. Tedium associated with the use of the traditional grinding stone, pestle and mortar has been eliminated through the use of disc-attrition mills.

5. Problems encountered by processors include; cost of fuel and labour, lack of credit facilities, unstable product (dough and *komi*) shelf-life, health effect of heat exposure and process characteristics.

4.6.2 Laboratory Investigations

1. The development of desirable organoleptic and physical qualities of maize dough such as sourness and viscosity (of cooked slurry of dough) required for good quality *komi* is a complex process involving biochemical and physical factors which act in concert or sequentially. Some of these factors are:

- soaking time
- soaking temperature
- initial moisture of dough
- fermentation time.

2. Dough souring (acidity) is initiated by steeping, and is sustained and propelled by fermentation. Beyond 48hr however, fermentation may become detrimental to the development of dough acidity, particularly in dough systems having initial moisture below 55%.

3. The degree of dough acidity is determined in part by the amount of moisture present in the system. High moisture content promotes high degree of souring, whilst insufficient water in the dough can lead to inadequate souring.

4. Dry-milling of maize leads to high dough acidity during fermentation.

5. The total time required for soaking and fermentation (in the traditional process) could be reduced from 72 - 144 hours to 48 hours just by observing the optimum processing conditions. The predicted optimum conditions are:

   Soaking temperature - room temperature (29°C)
   Soaking time - 17 hr.
   Initial moisture - 55%
   Fermentation time - 31 hr.

6. Soaking time was drastically reduced from 24 - 48hr to between 20 and 90 min by cracking of

maize and soaking at elevated temperatures (45° - 60°C) [Optimization process]. Short duration of soaking at elevated temperatures also favours acid production. Dough titratable acidity attained in a total time of 48hr using the traditional process was achieved in 24hr using the optimization process.

7. Viscosity of cooked slurry of dough increased with increasing fermentation time. This effect was greatly enhanced by steeping.

8. The effect of initial moisture on viscosity of cooked dough was inconclusive. Further investigation is recommended.

4.7 Future Work

The following are suggested areas for further work:

1. The regression equations obtained for dough titratable acidity and viscosity (of cooked dough) need to be tested in order to establish the optimum processing conditions.

2. Sensory evaluation to determine consumer preference for porridge (or *komi*) prepared from dough produced by the traditional and optimization process.

3. Evaluation of all the critical processes in *komi* processing leading to the development of convenient flour.

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APPENDIX 1

UNIVERSITY OF GHANA

DEPARTMENT OF NUTRITION AND FOOD SCIENCE

SURVEY ON KOMI PROCESSING IN GREATER ACCRA REGION

1. Town/Village:................................

A. RESPONDENTS

2. Age: ....
3. Marital Status: ....
4. If Married do you stay with your husband? ....Y\N
5. How many children do you have? ....
6. How many are attending\attended School? ....
7. Where are the children staying? ....
8. Do you have dependents? ....Y\N.
   Specify.................................
9. Education level:
   (a) Never
   (b) Elementary: Primary 1-6 ... Middle 1-4.....
   (c) Post Elementary..............................
10. Status
    (a) Processor (b) Processor and Retailer
11. How did you learn the trade?
    ....
12 For how long have you been in the business? .....
13. Did you inherit the business? ....Y\N.

14. If answer to 13 is yes, from who?...............

15. Do you have plans of passing it on?............

B. RAW MATERIAL

16. Where do you buy your raw materials from?

(a) Corn: ....

(b) Corn sheath ....

(c) Salt: ....

17. Do you buy the raw materials in bulk?...........Y\N

18. What are the terms of purchase? ....

19. Do you have special type of corn which you prefer?............................Y\N...

20. If yes, which type of corn do you prefer? ....

21. Why do you prefer this type(s) of corn to the others?....................................... ....

C. PROCESSING

22. Give detailed accounts of the process, what is done and the duration. ....

23. List the unit operations and their corresponding duration.

Operation	Duration
a)	....
b)	....
c)	....
d)	....
e)	....
f)	....
g)	....
h	....
i)	....
j)	....

24. What are the critical steps in the operation? List them.

Step	Importance
....	....
....	....
....	....
....	....
....	....
....	....

25. Do you encounter any problem(s) in the unit operations?................................Y\N

26. If yes, what problems do you encounter?

....

....

27. Suggest any improvement you want to see in the operation.

....

....

28. How often do you make the product? ....

29. Do you prepare the dough in large quantity and use it a little at a time? ....Y\N

30. How many days does it take to use all the dough?

....

D. EQUIPMENT

31. List the equipment needed for processing

Equipment	Type	Local\Foreign
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....

32. Which of these equipment do you own? List them.

Equipment	Life Span
....	....
....	....
....	....
....	....
....	....
....	....

33. Which of the equipment do you pay for services List them.

Equipment	Changes
....	....
....	....
....	....
....	....

E.COST OF INPUTS

34. A batch consist of .... corn to produce .... balls of kenkey.

35. List all the inputs for production.

Input	Amount in cedis\quantity used
a) Raw Material	
- Corn	....
- Corn sheath	....
- salt	....
b) Fuel	
- Firewood	....
c) Services	
....	....
....	....
....	....
d) Water	....

F. MARKETING AND STORAGE

36. How do you market your product? ....

....

....

37 What is the price(s) of a ball of kenkey?

....

38. Are you able to sell the batch the same day it is prepared? ....Y\N

39. If no, what do you do with the remainder of the product which is not sold?...................

....

40. How long does it take to sell a batch ofproduct?......................................

41. If answer to 38 is yes, do you intend to increase your size\frequency of output?..................

42. What are the constraints for expansion?.........

....

43. Do you get bulk order sometimes? ....Y/N

44. When or at what occasions do you get bulk orders?

....

45. Does seasonality affect sales of product? ....Y/N

46. Which part of the year are sales low?............

47. What do you do when sales are low?..............

....

48. Which part of the year are sales good?..........

49. What do you do when sales are good?..............

50. What account(s) for seasonality in sales?

....

51. Does customers buy on credit? .... Y/N

52. What are the terms of purchase?.................

....

53. How good is their credit worthiness?............

....

54. What is the mode for collecting the money?......

....

55. What is the shelf life of the product?.........

56. What is the best way for storing the product to maintain and prolong its quality after processing?................................

....

G. FINANCE/BY PRODUCT

57. How was the initial capital for the business obtained? ....

58. What proportion of the family income comes from this operation? ....

59. Does the family eat some of the products? ..Y/N

60. If yes, what quantity of product is eaten?

....

61. Do you eat some of the dough in a form other than komi?...

62. Does process have any by-products?..........Y/N.

63. What are the by-products?......................

64. What do you do with the by-products?...........

....

H. SUPPORT PERSONNEL

65. Do you receive assistance in making the product?...Y/N.

66. Who offers the assistance?

	Ages	Number
a. children	....	....
b. relatives	....	....
c. employees	....	....
d. other	....	....

I. MISCELLANEOUS

67. If a convenient flour is available will you buy it? ....Y/N.

Give reasons ....

68. Do you know of any kenkey sellers association? Y/N.....

69. Are you a member of the association?.........Y/N.

70. What benefits do association members enjoy over non-members?....................................

71. Is the product used as a weaning food?........Y/N.

72. In what form(s) is it administered?..............

73. Observation(s)...................................

....

Date....................