EFFECT OF HYDROTHERMAL TREATMENTS ON PROTEINS FROM ACHA (*Digitaria exilis*) AND *DURUM* WHEAT

BY

ISMAIL DUROJAIYE ABDULWAHAB

2003/14817EA

DEPARTMENT OF AGRICULTURAL AND BIORESOURCES ENGINEERING

SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY

FEDERAL UNIVERSITY OF TECHNOLOGY MINNA, NIGER STATE

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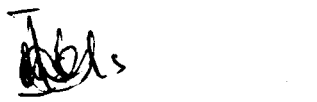
BEING A FINAL YEAR PROJECT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B. ENG.) DEGREE IN AGRICULTURAL AND BIORESOURCES ENGINEERING

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE

NOVEMBER, 2008

DECLARATION

I hereby declare that this project is a record of a research work that was undertaken and written by me. It has not been presented before for any degree or diploma or certificate at any University or Institution. Information derived from personal communications, published and unpublished works of others were duly referenced in the text..



19/11/2008

Ismail Durojaiye Abdulwahab — Date

2003/14817EA

CERTIFICATION

This project entitled "Effect of Hydrothermal Treatments on Proteins from Acha (*Digitaria exilis*) and *Durum* Wheat" by Ismail Durojaiye Abdulwahab meets the regulations governing the award of the degree of Bachelor of Engineering (B. ENG.) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

Engr. Dr. O. Chukwu	Date
Supervisor	
Engr. Dr. (Mrs.) Z. D. Osunde	24/11/2008 Date
Head of Department	
External Examiner	19-11-08 Date

DEDICATION

This project is dedicated to Almighty Allah

and

To all members of Ismail Durojaiye's family

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ABSTRACT

In this work, the effect of hydrothermal treatments on the protein contents of acha (*Digitaria exilis*) and *Durum* wheat was determined with a view of ascertaining their nutritional stability at various temperatures and heating durations. Standard Laboratory Scheme based on AOAC method for food analysis was used. Micro Kjeldahl nitrogen digestion and Markham distillation apparatuses were used to obtain the results of the analysis which indicated that heating acha and *durum* wheat samples between 70-140°C for 10 – 60 minutes results in 5.26 – 57.14 % and 1.13 – 14.29 % decrease in acha and *durum* wheat protein contents respectively. In general, proteins from acha and *durum* wheat are more susceptible to heat damage at high temperatures and long cooking times. The protein digestibility index was significantly altered by cooking between 70 -140°C for 10 – 60 minutes. Cooking at an extreme temperature and time (140°C and 60 minutes) reduced the protein content of acha and *Durum* wheat by 52.54 % and 13.16 % respectively. The possibility that protein contents of other cereals are also dependent on the duration of time and temperature to which they are subjected is important in the design of various processes and applications.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Protein is described as a substance found in meats, eggs, cereals, legumes, fish, certain vegetables and some dairy products such as milk and cheese. Essential proteins and vitamins could be obtained from peas, beans, and lentils as good sources of vegetable protein, while acha, wheat, barley, rye and soyabeans are the essential dietary sources of cereal protein and vitamins. Protein can be converted into carbohydrate through a process called gluconeogenesis.

Hydro and hydrothermal treatments constitute a major part of the unit operations carried out for processing of raw food materials. Hydrothermal treatments involved in processing cereals include boiling, washing, soaking and cooling. All these operations greatly affect both the cost and the efficiency of processing and evoke a spectrum of changes in the proximate compositions of the raw materials processed.

Cooking, a hydrothermal treatment, is the act of preparing food for eating by the application of heat. It encompasses a vast range of methods, tools and combinations of ingredients to alter the flavour or digestibility of food. It is the general preparation process of selecting, measuring and combining ingredients in an ordered procedure in an effort to achieve the desired result. Factors affecting the final outcome include the variability of ingredients, ambient conditions, tools, and the skill of the individual doing the actual cooking (Counihan and Van Esterik, 1997).They further stated that the diversity of cooking worldwide is a reflection of the myriad of nutritional, aesthetic, agricultural, economical, social and religious considerations that impact upon it.

Cereal grains such as wheat, corn, oats, barley, millet, sorghum, acha and rye are best for human nutrition when put into the form of flour, meal or flakes. The seeds of these grains consist of three parts; the germ containing oil (Vitamin E), the endosperm (interior part containing the starch) and the bran which is the protective covering containing fibre. The bran portion, also called mill feed, is sold mainly as an ingredient for cattle and sheep feeds but has become important as fibre in a healthy diet. The amount of germ in cereal grains varies from less than 2 percent in wheat to more than 10 percent in corn and because of high oil content, the germ is often roasted and sold vacuum - packed to prevent its becoming rancid. The germ oil can be pressed out in the milling industries and sold as cooking oil (David *et al.*, 2004). Foods containing cereal flours have been very important to human nutritional needs since ancient time and in United States, most cereal flours are enriched with Vitamin B1, Vitamin B2, niacin, and iron. Vitamin D and calcium are also added to flours for use in areas where flour is a primary nutritional source.

Wheat flour is consumed in larger quantities worldwide than any other cereal flour. This is because of its extensive availability. Wheat can be grown under widely varying climatic conditions and it contains a protein called gluten. When wheat flour is mixed with water, the gluten forms elastic dough, and when the dough is baked in a hot oven it expands to several times its original volume. Flour made from soft wheat containing less than 12 percent of gluten protein is used to make tender products such as cakes and crackers while flour made from hard wheat containing more than 12 percent protein is used for bread and roll production (David *et al.*, 2004).

Cooking of acha and *durum* wheat or other grains often involves water which is frequently present as other liquids, both added in order to immerse the substances being cooked (typically water, stock or wine) and released from the foods themselves. Liquids are so important to cooking that the name of cooking method used may be based on how the liquid is combined with the food, as in steaming, simmering (an act of cooking something by keeping it almost at boiling point), boiling, braising (act of cooking any substance e.g. meat or vegetables very slowly with a little liquid in a closed container) and blanching. Heating liquid in an open container results in rapidly increased evaporation which concentrates the remaining flavour and ingredients (Routledge, 1997). An emulsion of starch with fat or water can, when gently heated, provide thickening to the dish being cooked. In Europe, cooking a mixture of butter and flour called a roux is used to thicken liquids to make stews or sauces. In Asia, cooking to achieve a similar effect is obtained from a mixture of rice or corn starch and water. These techniques rely on the properties of starches to create simpler mucilaginous saccharides during cooking, which cause the familiar thickening of sauces. This thickening will breakdown under additional heating (Routledge, 1997).

Applying heat to food usually, though not always, chemically transforms it, thus changing its flavour, texture, consistency, appearance, and nutritional properties. There is archaeological evidence of roasted foodstuffs, both animal and vegetable composites dating from the earliest known use of fire, some 800,000 year ago. Other methods of cooking that involve the boiling of liquid in a receptacle have been practised at least since the10th millennium BC, with the introduction of pottery. (Routledge, 1997).

The main purpose of this study is to examine the effect of heat processing on the protein content extracted from acha and *durum* wheat, including other uses of cereal grains that might be predicted. Knowledge of cereal and other grains in this study will aid in assessing the heat treatment, processes and other unit operations that acha and *durum* wheat grains may be subjected to, in order to enhance their maximum utilization.

1.2 Statement of the Problem

In Nigeria and many other African countries, little information exists about the nutritional composition of acha and *durum* wheat. Although these grains are sold in the market most Africans do not know their importance to human diet.

1.3 Objectives of the Study

i. To determine the protein content of acha and *durum* wheat at different temperatures before and after cooking.

ii. To determine the effect of cooking on protein from acha and *durum* wheat.

iii. To determine the temperature at which the maximum protein content can best be obtained from acha and *durum* wheat

1.4 Justification of the Study

Nutritional analysis has proved that acha and *durum* wheat are among the essential sources of protein from cereal crops. Acha and *durum* wheat are so important in human diet and are very unique in that they have greater methionine and gluten content respectively than other cereal crops (Jideani, 1990).The protein content in acha makes it a medically recommended diet for diabetic patients. Therefore this project is undertaken to

evaluate the behaviour of proteins from acha and *durum* wheat at different temperatures during heating.

1.5 Scope of the study

The scope of this project work is limited to the determination of protein contents of acha and *durum* wheat at different temperatures during heat treatment.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and Evolution of Acha and Wheat

Acha (Digitaria exilis kippil stapf) also known as "*fonio*", "*findi*" or "Hungry rice" is one of the indigenous African cereals which belong to the family of the *Poaceae* (grasses), the most economically and ecologically important family of the monocotyledon (Rachie, 1974). The genius *Digitaria* is quite large worldwide in distribution and represents the seventeen species in Nigeria (Standfield, 1970). Acha is one of the most nutritious of all grains because its seed is very rich in methionine and cystine (amino acids) which are vital to human health.

Acha (*Digitaria exilis* and *Digitaria iburua*) is an annual cereal crop indigenous to West Africa where it is cultivated for its straw and edible grains. It is probably the oldest African cereal. For thousand of years, West Africans have cultivated it across the savannah. Indeed, it was once their major food crop. This crop is important in areas scattered from Cape Verde to Lake Chad, in certain regions of Mali, Burkina Faso, Guinea and Nigeria. It is widely grown in the cool region of Plateau State, parts of Bauchi, Kebbi, Taraba, Kaduna and Niger States. It is either the staple food or a major part of the diet. Each year West African farmers devote approximately 300,000 hectares to acha cultivation and yields of 600-700kgha^{-1}are recorded which translate to 180,000-210,000 tonnes of grains annually. The crop supplies food to 3-4 million people (Jideani, 1990; NRC, 1996). Acha protein is reported to be unique in that it has greater methionine content than other cereals (Jideani and Akingbala, 1993). The two species of acha are high in digestible energy but low in oil and minerals.

Digitaria exilis stapf is an annual cereal plant which is cultivated for its straw and edible grains. The plant grows well on poor, sandy, or ironstone soil in areas of low rainfall. In Northern Nigeria, the grain of *Digitaria exilis*, commonly called acha or hungry rice is harvested 3 - 4 months after sowing. It is one of the staple cereal foods in Northern Nigeria during the dry season. Acha grain can be ground into flour and used to prepare local beverages; it can also be used to prepare feeds for domestic animals.

Digitaria exilis is a small cereal grain of ancient cultivation, widely grown in West Africa and dry savannah zones of Mali, Burkina Faso, and Guinea. It is widely grown in Nigeria in cool regions of Plateau State, parts of Bauchi, Kebbi, Taraba and Niger States. Among the cultivated types, two species are prominent namely, white acha (*Digitaria exilis*) and brown acha (*Digitaria iburua*). White acha is a semi-erect/straggly annual plant. It is also hairless, having a height ranging from 102 - 123cm and rooting sometimes at the lower nodes. The stem which is known as culm is sparingly branched from below with about 5 - 8 nodes.

The consumption of acha (*Digitaria exilis*) is expanding rapidly among Nigerians as an alternative to rice, and experts acknowledge that it has exceptional qualities. In contrast to other cereals, the germ which is rich in fat never disappears completely with the de-hulled grain. The de-hulled grain of acha contains particularly no lipids. This is another reason why interest in this crop is growing among agriculturalists, and in June 1994, the programme for the promotion of indigenous cereal of the Sahel in Bamako, Mali, dedicated an international workshop to acha. The genius *Digitaria* is represented by about 300 species of annual and perennial grasses (Bogdan, 1977).

A large number of these species such as *Digitaria horizontalis*, *Digitaria leptorhachis and Digitaria sanguinalis* are recognized as weeds while others like *Digitaria decumbers stent*, *Digitaria eriantha stent* and *Digitaria-macroblephora stapf* have been cultivated as forage crops yet others such as *Digitaria exilis stapf* and *Digitaria iburua stapf have* been cultivated as human cereals (Halm *et al.*, 1971; Oates *et al.*, 1959; Foster *et al.*, 1961; Rooney, 1961 and Steel, 1976).

Being one of the small seeded cereal crops (small millets), *Digitaria exilis* is said to have great genetic and developmental potentials. Acha has a long storage life and high keeping quality, and has a potential for replacing the so-called super cereals in industrial and food products of tomorrow (Harinaraya, 1986).

Brown acha (*Digitaria iburua*) is erect in growth with height of 140-150cm (Dachi *et al.*, 1995). The lower internodes of both types of acha are usually shorter while the uppermost internodes are the longest bearing, ranging from 4-6 spikes and the seeds are found on the spikelets. A single grain of the crop can produce a multiple of stems on a single stand .The leaf sheaths are usually held tight to the stems while the leaf blade is approximately 13 to15cm long depending on the accession (Dachi *et al.*, 1995). This can be grown in Bauchi and Plateau States of Nigeria as well as Northern regions of Togo and Benin Republic.

The standard nutritional contents of acha food are approximately the following: protein 8.5 % (typical of cereals), Fat (1.1 %), carbohydrate (81.0 %), fibre (1.1 %), and ash (2.1 %) (Purseglove, 1985). Anon (1970) and (Bento *et al.*, 1986) reported high level of methionine and cystine of about 7.3 % unlike other cereals. Acha is complementary to legumes which are known for low methionine contents and a medically recommended

diet for diabetic patients due to its richness in protein content compared to other cereals. Acha is moderately resistant to disease, and has very long storage ability that ranges from 10-40 years. It is an effective means of erosion control and can suppress weed growth at seven weeks after planting (Dachi, 2000).

(Counihan and Van Esterik, 1997) stated that if heat is used in the preparation of food, it can kill or inactivate potentially harmful organisms including bacteria and viruses. The effect will depend on the temperature, cooking time and technique used. The temperature range from 5^0C to 75^0C is the food danger zone. Between these temperatures bacteria can grow rapidly. Under optimal conditions, *E. coli,* for example, can double in number every twenty minutes. The food may not appear any different or spoiled but can be harmful to anyone who eats it. Meat, poultry, dairy products, and other prepared foods must be kept outside of the food danger zone to remain safe to eat. Refrigeration and freezing do not kill bacteria, but only slow their growth. When cooling hot food, it should not be left on the side or in a blast chiller (an appliance used to quickly cool food) for more than 90 minutes.

Digitaria exilis and *Digitaria iburua* are the two utilized varieties of acha crop grown throughout the Savannah zone of West Africa. *Porteres* (1955) stated that there are about fifteen types of *Digitaria exilis* in the Futa Djallon highland of Guinea and its surroundings. *Digitaria exilis* is also found along the upper basins of the Senegal and Niger-rivers and on banks of the basins. Porteres (1955) further reported that movement eastward as far as Chad, the number decreases and that the centre of discernable varietal diversification is situated in the upper basin of the Niger from the river's source to the central Delta region.

Dachi *et al* (1995) reported that *Digitaria iburua* differs from *Digitaria exilis* in the packed arrangement of spikelets, height (taller), black seed coat, longer internodes and peduncle, angular scarbrid pedicels, short delicate upper glume and is harder to dehull than *Digitaria exilis.*

Acha (*Digitaria exilis* and *Digitaria iburua stapf)* is fast food and lack of processed products is holding back Africa's native grains. One grassroot organization is doing something about this; it is turning acha into a convenient food. In Southern Mali, acha is mainly grown by women on their individual plots. Perhaps, not unexpectedly, then it is women group that has chosen to foster the grains greater use. The group's aim is to raise acha consumption by producing pre-cooked flour. The project tagged Malians Association for the Promotion (AMP) of acha is staffed and run entirely by women. The major importance of it, is that, it is a fast cooking acha that will challenge parboiled rice and pre-packaged pasta (both of which are usually imported) into Bamako markets. The new "instant" acha comes in 1kg plastic bags and is ready for use. It requires no pounding or cleaning. It can be used to prepare all of the traditional acha dishes. It is simple to store and handle. It is cleaned and free from hulls and dirt, and it requires less than 15minutes cooking. For the users, it offers an enormous saving in both effort and time. The project is currently a small one, designed to handle 6 tonnes of raw acha per year. It uses local materials, traditional techniques, and household equipment: mortars, tubs, calabashes, steaming pots, sieves, matting, kitchen scales and small utensils. The women sieve, crush, wash and steam-cook the acha, and then they dry and seal the product in airtight bags. The most delicate operation is a series of three washings to separate sand from the tiny acha grains.

The women have organized themselves into small working groups, formed for the supply of raw materials, production, packaging and marketing. Acha is considered a prestige food in local culinary customs. This small homespun exemplifies what could be done with native grains throughout Africa. It is good for everyone diversifying the diet of city folks, reducing food imports, and above all benefiting the local farmers by giving them a value added product (Abdulkadir, 2007).

(Cisse, 1975) reported that several varieties of acha in Gambian region are classified according to the colour of the grain (red, black, or white) and the time of maturity. Early to medium maturing varieties (60-120 days) are found in lower rainfall areas and can be cropped twice or thrice in a year in Guinea where the duration of the rainy season permits (Johnson, 1958). Longer duration varieties (120-150 days) tend to be taller (60-75cm) and higher yielding with large grains. Bakere *et al* (1998) noted that for profitable grain yield of acha, planting should be within the month of May and June and should not extend to July at Badeggi in Niger State, Nigeria.

Wheat is one of the more nutritious cereals and its contribution to the human diet puts it clearly in the rank of plant to feed the world. Wheat (*Triticum spp*) is a domesticated grass from the *Levant* that is cultivated worldwide. Wheat is an important human food, its production being second only to maize among cereal crops, rice ranks third. Wheat grain is staple food used to make flour for leavened, flat and steamed bread, cookies, cakes, pasta, noodles and cous cous, and for fermentation to make beer, alcohol, vodka, or biofuel (Padulosi and Hammer, 1996; Bonjean and Angus, 2001).

Wheat (*Triticum aestivum*) is planted to a limited extent as a construction material for roofing thatch. The popularity of wheat species as food is because of its relatively high

protein content, but it is also used as feed for livestock. Wheat is divided into classes of species on the basis, principally of kernel characteristics and growth habits. The classes are hard red winter, hard red spring, soft red winter, white, *durum* and club wheat (Douglas *et al.,* 1983). However, the name of wheat specie from one information source may not be the name of wheat specie in another. Within a specie, wheat cultivars are classified by wheat breeders and farmers in terms of growing season (such as winter wheat versus spring wheat), by gluten content such as hard wheat (high protein content) versus soft wheat (high starch content)) or by grain colour (red, white, or amber) (Padulosi and Hammer, 1996; Bonjean and Angus, 2001).

Wheat originated in Southwest Asia in the area known as Fertile Crescent. The genetic relationship between *Einkorn* and *Emmer* indicate that the most likely site of domestication is near Diyarbakir in Turkey. These wild wheats were domesticated as part of the origin of agriculture in the Fertile Crescent. Cultivation and repeated harvesting and sowing of the grains of wild grasses led to the domestication of wheat through selection of mutant forms with tough ears which remained intact during harvesting, larger grains, and a tendency for the spikelets to stay on the stalk until harvested. Because of the loss of seed dispersal mechanisms, domesticated wheat has limited capacity to propagate in the wild (Padulosi *et al.*, 1996; Bonjean *et al.*, 2001). It was also said that wheat originated in Asia and was first grown in North America in the Seventeenth Century. It is now the leading small cereal grain in acreage and production in the United States. It is grown in every state in the nation except in the New England State. Wheat is today one of the most important of all cultivated plants with respect to human nutrition. It is the only

crop so far reported to produce more than 400 million metric tonnes in a single year (FAO, 1978).

Edible animal material, including muscle, offal, milk and egg white, contains substantial amounts of protein. Almost all vegetable matter (in particular legumes and seeds) also includes protein, although generally in smaller amounts. These may also be a source of essential amino acids. When proteins are heated they become de-natured and change texture. In some cases, proteins can form more rigid structures, such as the coagulation of albumen in egg white. The formation of a relatively rigid but flexible matrix from egg white provides an important component of much cake cookery, and also underpins many desserts based on meringue (a sweet white mixture made from egg white and sugar, usually baked until crisp and used to make cakes) (Counihan and Van Esterik, 1997). The edible portion of the contents of bread wheat grain (hard red spring type) per 100g is shown in Table 2.1.

In the production and international trade estimates of FAO, the average world production of wheat grain (bread wheat and *durum* wheat) in 1999-2003 amounted to 576 million tonnes/year from 209 million hectares. Worldwide, bread wheat constitutes more than 90% of the area under the cultivating for wheat. The main wheat producing countries are China (96.8million tonnes/year from 25.2 million hectares), India (71.0million tonnes/year from 26.4 million hectares), the United States (56.9 million tonnes/year from 20.6 million hectares) and France (35.1 million tonnes/year from 5.0 million hectares). Wheat production in tropical Africa in 1999-2003 was 2.5 million tonnes/year from 1.6 million hectares, the main producing countries being Ethiopia (1.4 million tonnes/year from 1.1 million hectares), Kenya (272,000 tonnes/year from 137,000 hectares), Sudan

Table 2.1 Bread Wheat (hard red spring type) constituents per 100g edible portion

Constituents	Quantity per unit
Water	12.8 g
Energy	1377 kJ
Protein	15.4 g
Fat	1.9 g
Carbohydrate	68.0 g
Dietary fibre	12.2 g
Calcium	25 mg
Magnesium	124 mg
Phosphorous	332 mg
Iron	3.6 mg
Zinc	2.8 mg
Thiamin	0.50 mg
Riboflavin	0.11 mg
Niacin	5.7 mg
Vitamin B_6	0.34 mg
Folate	43µg
Ascorbic acid	0 mg

Source: Brink *et al.*, 2006

(254,000 tonnes/year from 124,000 hectares) and Nigeria (75,000 tonnes/year from 53,000 hectares) (Lantican, 1999).

The cultivation of wheat began to spread beyond the Fertile Crescent during the Neolithic period. By 5,000 years ago, wheat had reached Ethiopia, Indian, Great Britain, Ireland and Spain. A millennium later it reached China. Three thousand years ago agricultural cultivation with horse drawn ploughs increased cereal grain production, as did the use of seed drill to replace broadcast sowing in the 18th century. Yields of wheat continued to increase, as new land came under cultivation and with improved agricultural husbandry involving the use of fertilizers, threshing machines, and reaping machines (the combine harvester), tractor-drawn cultivators, planters and better varieties. In 2007 wheat stocks have reached their lowest since 1981, and 2006 was the first year in which the world consumed more wheat than the world produced- a gap that is continuously widening as the requirement for wheat increases beyond production (Padulosi and Hammer, 1996; Bonjean and Angus, 2001).

Durum wheat kernel is sometimes called the wheat berry. The kernel is the seed from which the wheat plant grows. Each tiny seed contains three distinct parts that are separated during the milling process to produce flour. The endosperm is about 83% of the kernel weight and the source of white flour, the endosperm contains the greatest share of protein, carbohydrates, and iron as well as the major B-vitamins, such as *riboflavin*, niacin, and *thiamine*. It is also a source of soluble fibre. The bran flour is about 14% of the kernel weight. Bran is included in whole wheat flour and can also be bought separately. The bran contains a small amount of protein, trace minerals, and dietary fibre (primarily insoluble).

Wheat germ is about 2.5% of the kernel weight. The germ is the embryo or sprouting section of the seed. It is often separated from flour because the fat contents (10%) limit shelf life. The germ contains minimal quantities of high quality protein and a greater share of B- complex vitamins and germ is a part of whole wheat flour and can be purchased separately as trace minerals (Padulosi and Hammer, 1996; Bonjean and Angus, 2001).

Wheat grain is a staple food used to make flour for leavened flat and steamed breads, cookies, cakes, pasta, noodles and cous cous, and for fermentation to make beer, alcohol, vodka or bio fuel. Wheat is planted to a limited extent as a forage crop for livestock, and the straw can be used as fodder for livestock or as a construction material for roofing thatched houses (Padulosi and Hammer, 1996; Bonjean and Angus, 2001; Wikipedia, 2008).

Wheat and flour specifications are communications between buyers and sellers. These specifications are requirements for particular wheat and flour characteristics. To meet these specifications, wheat and flour quality testing is necessary. Specifications for moisture content, ash content and protein content are determined with basic tests. Physical tests included are required to determine flour colour and wheat kernel characteristics specified by wheat processors. The laboratory milling is used to evaluate the milling performance of wheat and to produce flour for other laboratory tests. The wet gluten test measures the amount of gluten protein in flour, the starch properties of flour are measured by amylograph and rapid visco analyzer tests (David *et al.*, 2004).

It has been suggested that cooking changes solubility characteristics of sorghum protein in general and that of prolamin (*kahrin*) proteins in particular (Rooney *et al.*, 1986). Heat

processing is reported to improve the digestibility of seed protein by destroying protein inhibitors and opening the protein structure through denaturation (Hist *et al.*, 1977). However, heat processing can also cause decrease in the digestibility through non-enzymatic browning reactions and thermal crosslinking (Tannenbaum 1974; Rooney *et al.*, 1986).

The effect of heat processing on the extractability, in-vitro digestibility and electrophoretic profiles of acha protein has been reported (Jideani *et al.*, 1994). The amino acid compositions and Sodium Dodecyl Sulphate Polyacrylamide gel electrophoresis (SDS-PAGE) of residual protein produced after extraction with various solvent systems have also been reported. Similar investigations were also conducted with *durum* wheat and the results are discussed in terms of inter- subunit forces within the proteins from acha to *durum* wheat. In general, the studies showed that the extractability of heated and unheated samples was dependant on hydrophobic disulphide (S-S) and hydrogen bonding. However, a significant proportion of acha protein was apparently not affected by SDS and S-S reducing agents (Jideani *et al.*, 1994).

2.2 Uses of Acha and *Durum* Wheat

Acha and wheat remain vital to food security of millions of African farmers who use acha and wheat in several ways as shown in Table 2.2

2.3 Protein and Essential Amino Acids of Acha and Wheat

The Amino acid composition of wheat meal, acha and durum flour and residual proteins are shown in Table 2.3 (Carbiener *et al.*, 1960; de Lumen *et al.*, 1986, and Temple and Bassa, 1991). Using a Spearman's rank correlation test, it was established that the four results for acha were not significantly different ($p = 0.01$). The unit used for

Table 2.2: Uses of *Acha* and *Durum* Wheat

	Uses of *Acha*	Uses of *Durum* wheat
1	Acha can be cooked as porridge	Wheat can be planted to a limited extent as a forage crop for livestock.
2	It can also be used for making cous cous	It can be used to make noodle and cous cous
3	Acha can be mixed with other flours to make bread, and can be used for preparing beverages.	Hard-white wheat which is coloured, light coloured, opaque, chalky and medium protein wheat planted in dry temperate areas is used for bread and brewing.
4	It can be brewed for beer.	It can be fermented to make beer, alcohol and vodka.
5	The husk is used as a source of fuel for cooking	The straw can be used as fodder for livestock or as a construction material for roofing thatch.
6	It is used for preparing feeds for domestic animals	Soft low protein wheat is used for cakes, pie crusts, biscuits, and muffins.
7	It can be cooked into various forms with meat, fish, legumes or vegetables for man.	It can be used for making spaghetti-type flour

Source: Bonjean and Angus (2001); Douglas *et al* (1983).

amino acid measurements by Temple and Bassa (1991) as well as Carbiener *et al* (1960) was 1g per 16g/N, and that used by de Lumen *et al.*, (1986) was per 100g of protein. Jideani *et al* (1994) employed mol %, i.e. number of amino acid residues per 100 residues. The statistical test used was independent of the unit of amino acid measurement. The higher than expected alanine values obtained by Jideani *et al* (1994) (Table 2.3) were due to the overlap with the peak for ammonia in the amino acid analysis.

The low extractability of acha protein residue compared to *durum* wheat protein residues appears to be related to the significantly higher levels of hydrophobic amino acids, glutamines and cystine in the former. Thus acha and *durum* protein residues contained

respectively 32.9 mol% and 21.1 mol% of hydrophobic amino acids, 17.9 mol% and 12.8 mol% glutamines and 2.1 mol% and trace levels of cystine (Table 2.3). Therefore the lower solubility of acha protein can be ascribed to a greater inter-subunit hydrophobic interaction, hydrogen bonding and disulphide links.

Protein solubility might also depend on the spatial arrangement of particular amino acid residues. Thus hydrophobic groups might form hydrophobic patches at the side of coil (helical) structures. The overall spatial arrangement of gluten subunits may also distinguish the soluble from the insoluble gluten or residue proteins (Ewart, 1990).

The amino acid compositions of acha and durum glutelin and residual proteins showed the same high levels of glycine, glutamate/glutamine, proline and leucine (Table 2.3).

Table 2.3: Amino Acid Composition of *Durum* Wheat and Acha Protein (Tryptophan was not Determined)

Amino acids	*Durum wheat*				*Acha*			
	Omen and Bushuk (1970) (μmol amino acids per mg N) (WF)	Jideani *et al.*, 1994 (mol%)[b,c] (WF)	Jideani *et al.*, 1994 (mol%)[b,c] (RES)	Carbiener et al., (1960) (g per 16 g N)[C] (WF)	de Lumen et al.,(1968) (g per 100 g of protein)[c] (WF)	Jideani *et al.*, 1994 (mol%)[b,c] (WF)	Jideani *et al.*, 1994 (mol%)[b,c] (RES)	Temple and Bassa (1991) (g per 16 g N) (WF)
Aspartic acid	1.89	5.1 ± 1.3	7.1	6.5	7.2	7.2 ± 1.5	5.9	3.5
Glutamic acid	13.20	23.0 ± 5.7	12.8	20.2	18.8	18.2 ± 3.3	17.9	6.9
Cysteine	0.60	1.7 ± 0.5	Trace	2.8	2.5	2.5 ± 0.3	2.1	3.0
Serine	2.26	7.1 ± 0.8	6.5	5.1	5.0	7.9 ± 0.6	7.4	2.2
Glycine	2.54	6.9 ± 0.7	10.4	3.2	3.8	6.5 ± 0.3	5.7	1.9
Histidine	0.83	1.6 ± 0.5	Trace	2.1	2.3	1.4 ± 0.4	1.9	1.4
Arginine	1.13	3.1 ± 0.7	1.2	3.8	4.8	2.1 ± 1.4	1.1	1.3
Threonine	1.29	33.3 ± 1.1	3.5	4.0	3.9	4.9 ± 0.3	5.2	1.0
Alanine	1.99	14.2 ± 5.3	33.2	9.0	8.4	11.4 ± 3.5	17.7	4.2
Proline	6.56	10.5 ± 1.4	6.3	7.1	6.4	7.2 ± 1.2	9.0	3.2
Tryptophan	0.80	2.2 ± 0.5	1.4	3.6	3.1	2.2 ± 1.8	1.2	1.0
Valine	2.21	5.2 ± 1.0	4.2	5.8	5.5	6.1 ± 1.5	4.7	2.4
Methionine	0.78	0.8 ± 0.5	1.2	5.6	4.8	3.7 ± 2.2	2.0	3.0
Isoleucine	1.87	3.4 ± 0.5	2.0	4.0	3.8	3.2 ± 1.1	3.0	1.4
Leucine		6.9 ± 0.2	5.4	9.8	9.8	8.8 ± 1.2	10.6	4.5
Phenylalanine	1.80	3.2 ± 0.1	2.0	5.1	5.2	3.1 ± 0.6	3.6	2.3
Lysine	0.85	1.7 ± 0.2	1.1	2.6	3.1	1.3 ± 0.3	2.8	1.9
Ammonia	12.50							
Classified distribution of amino acids								
Hydrophobic		25.9	21.1			41.0	32.9	
Uncharged polar		21.9	21.8			21.5	17.5	
Basic		6.4	2.3			3.8	5.8	
Acid		31.6	19.9			21.1	23.8	

[a] Residue was obtained after extraction of flour with Osborne classical solvent; WF – Wholemeal flour; RES: residue

[b] Mean of three replicates

[c] For Acha b(WF), c(WF), d(WF), and e(WF) are positively correlated (P=0.1)

[d] Ammonia and Alanine peaks overlap in the results of the present work. [e] According to Rupnow(1992) except that alanine was omitted from Class 1

Source: Jideani *et al.*, 1994.

2.4 The Effect of Cooking on Protein from Acha and *Durum* Wheat

The effect of cooking on protein from acha and *durum* wheat assessed from an analysis of protein extractability, gel electrophoretic profiles, in-vitro protein digestibility (IVPD) and the amino acid compositions of wholemeal flour samples at 100-140°C(time = 10-40 min) resulted in 0-30% and 45-55% decreases in acha and *durum* protein solubility, respectively. In general, high molecular weight (30-70kDa) (where kDa = kilodalton mostly used when talking about protein molecules) protein subunits were more susceptible to heat damage. For both cereals, sodium dodecyl sulphate (SDS; 10g/litre) and dithiothreitol (DTT; 10mM) increased protein solubility in unheated and heated samples (Jideani *et al.*, 1994).

According to Jideani *et al* (1994) the IVPD index was 90-91% and was not significantly altered by cooking between 100 and 120^{0}C for 40 minutes. Cooking at extreme temperatures (140^{0}C, time = 40 minutes) reduced the IVPD by 8% as shown in Figure 2.1. The effect of cooking temperature of water on the solubility of acha and *durum* wheat proteins is also shown in Figure 2.1. They further reported that wholemeal acha flour and residue protein showed a significantly greater level of hydrophobic and sulphur amino acids as well as glutamine which are associated with H-bonding.

Due to the changes in the solubility of *durum* wheat and acha protein on cooking Jideani *et al* (1994) recorded an apparent changes on protein solubility on cooking from acha and wheat flour in water at 80^0-140^{0}C, protein solubility for the uncooked grains is taken as 100%.They further stated that the SDS-protein of acha and *durum* protein extracted from the grain after cooking at various temperatures was noticed. In the case of *durum* protein from sample cooked at 140^{0}C for 40 minutes, they stated that cooking in water at

120^0C-140^0C reduced the solubility of *durum* protein by 50%, and that protein bonds perhaps indicating the aggregation of *durum* proteins occurred in cooking; also that uncooked acha sample contains protein. However, at temperatures of 120^0 and 140^0C, a more diffuse SDS-PAGE pattern was obtained, protein fragmentation may have occurred as a result of peptide bond hydrolysis and there was no protein at the point of application.

A decrease in the levels of free amino acids from 1.9 to 1.4mg/kg (dry weight bases) was reported when whole wheat grains were cooked in live steam at 121^0C for 40 minutes (Clawson and Taylor, 1993). There was a concomitant decrease in the level of reducing sugars.

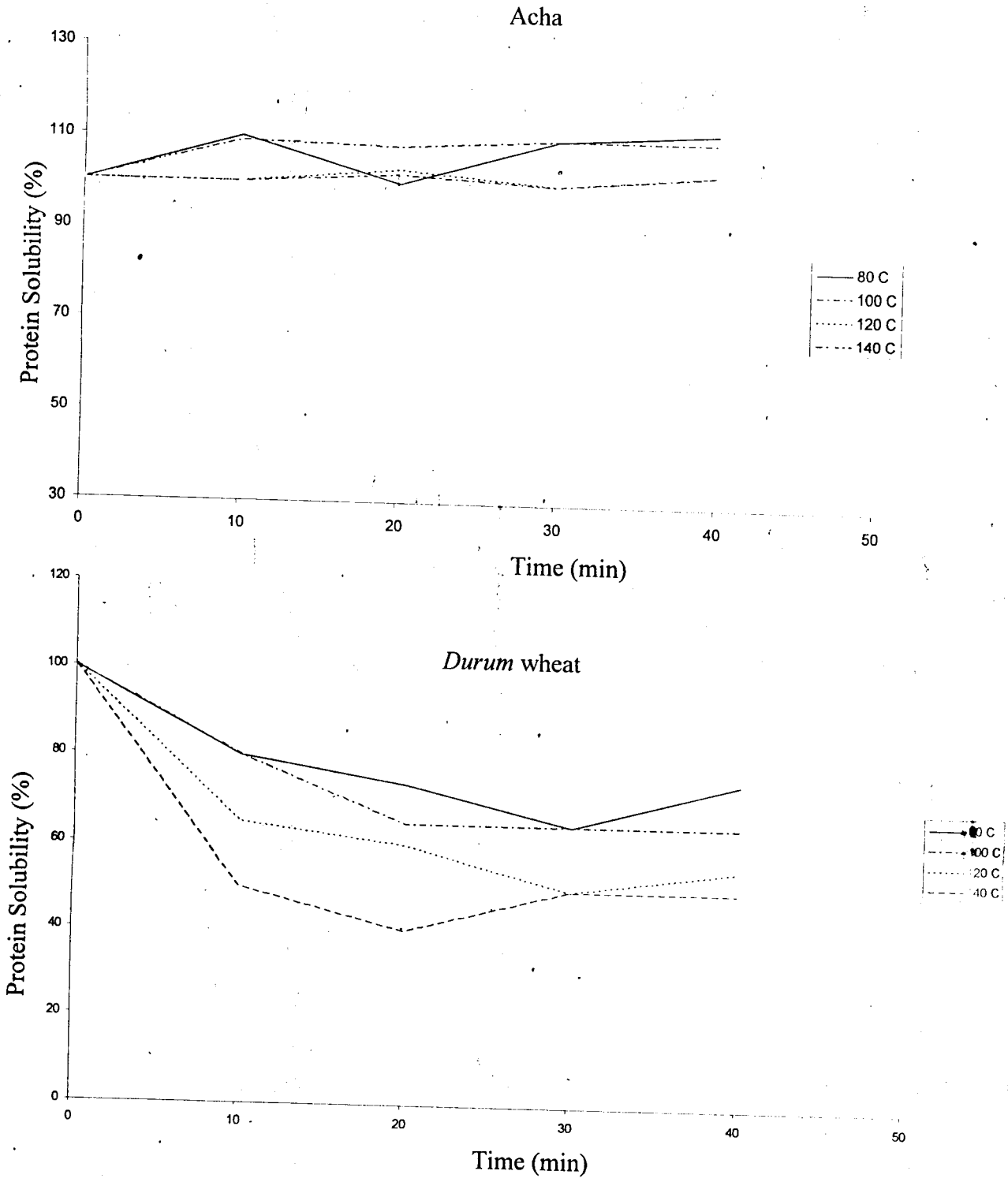

Fig. 2.1: Effect of cooking temperature of water on the solubility of acha and *durum* wheat proteins

Source: Jideani *et al.*, 1994.

2.5 Changes in the Solubility of Acha and *Durum* Wheat Proteins on Cooking in Salt Solution

According to the Osborne classification, cereal albumin and globulin are extractible in 0.1M NaCl solution at 0 - 4^{0}C, when 0.5 M NaCl solutions were used as a cooking medium. The changes in protein solubility were as shown in Fig. 2.2. There was a decrease in the solubility of *durum* protein as cooking temperature was increased.

Cooking of acha at 100 - 120^{0}C also led to a decrease in protein solubility. However, at 140^{0}C, there was a distinct increase in solubility after heating for 10 – 40 minutes. A similar, but small increase was also observed for *durum* at this temperature.

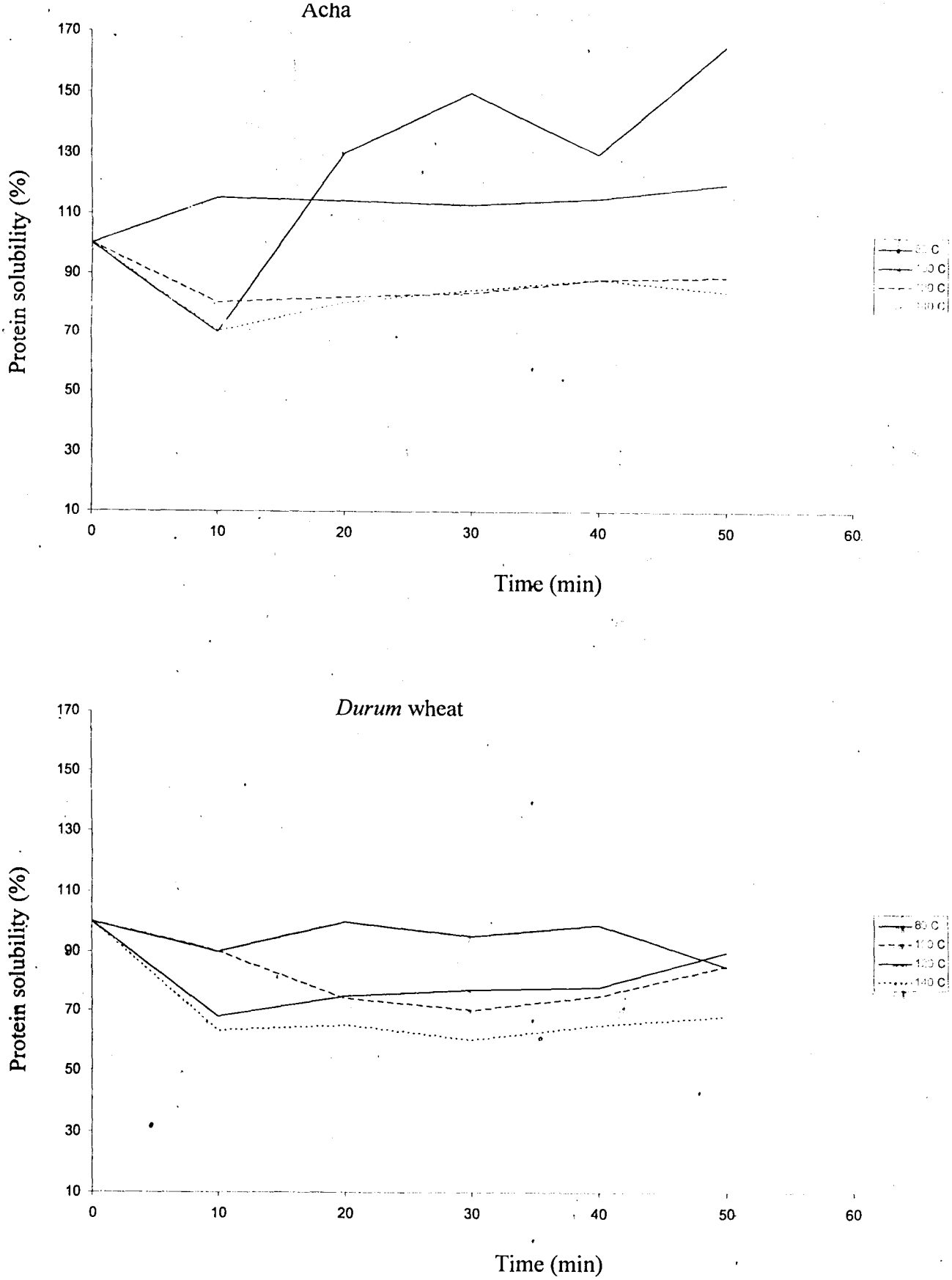

Fig. 2.2: Effect of Cooking Temperature on the Solubility of Proteins of Acha and *Durum* Wheat in Solution of 0.5M Sodium Chloride

Source: Jideani *et al.*. 1994.

2.6 In-vitro Protein Digestibility (IVPD) of Cooked and Uncooked *Acha* and *Durum* Wheat

In-vitro protein digestibility values for cooked and uncooked acha and *durum* wheat using pepsin are given in Table 2.4. In general both cooked and uncooked acha were almost as digestible as cooked and uncooked *durum* wheat. There was not much change in the IVPD for acha and *durum* wheat samples at the cooking temperatures and times examined. Similar results were obtained for the pepsin digestibility of wheat, maize and rice following cooking (Hamaker *et al.*, 1986). Although pepsin (P) is an acidic enzyme, the results for sorghum digestibility obtained with it were similar to those obtained by Hamaker *et al* (1986) using trypsin-chymotrypsin (TC) or the multiple enzyme method (P-TC). The IVPD of uncooked acha was 90.8% as compared with a value of 91.7% for *durum* wheat (Table 2.4).

With an increase in cooking time the digestibility of acha did not decrease significantly in either water or salt solution except after 40 minutes at 140^0C when the IVPD value decreased by 8% (Table 2.4). On the basis of these results the acha grain would therefore be suitable as a good source of calories and digestible protein for many people living in semi-arid tropics who depend largely on sorghum grain supplies (Jideani, 1990).

Table 2.4: Effect of Heat Treatment on In-vitro-Digestibility of Acha and *Durum* Wheat (mean ± SD, n =3) (treatment involved cooking in water or 0.5 M NaCl solution at specific temperatures and times)

Treatment	% Protein	% IVPD	% Decrease in IVPD from uncooked
Acha	7.4 ± 0.31		
Uncooked	0.7 ± 0.04	90.8 ± 0.66	
Water,100^{0}C,10 min	0.6 ± 0.06	91.6 ± 0.84	
Water,100^{0}C,40 min	0.8 ± 0.06	89.2 ± 0.86	1.73
Water,140^{0}C,10 min	0.8 ± 0.06	90.8 ±0.85	0.93
Water,140^{0}C,40 min	1.2 ± 0.13	83.5 ± 1.72	8.07
Salt solution,100^{0}C,10 min	0.8 ± 0.01	89.4 ± 0.08	1.55
Salt solution,100^{0}C,40 min	0.8 ± 0.06	88.7 ± 0.81	2.27
Durum wheat	14.7 ± 0.12		
Uncooked	1.2 ± 0.16	91.7 ± 1.06	
Water,100^{0}C,10 min	1.5 ± 0.05	90.0 ± 0.37	1.85
Water,100^{0}C,40 min	1.7 ± 0.11	88.2 ± 0.75	3.87
Salt solution,100^{0}C,10 min	1.3 ± 0.02	91.2 ± 0.11	0.57
Salt solution,100^{0}C, 40 min	1.4 ± 0.01	90.3 ± 0.05	1.50

SD = Standard Deviation, n= number of replications

Source: Jideani *et al.*, 1994

2.7 Starch Isolation

Starch was isolated by the wet milling procedure of Akingbala (1982) as outlined in Fig. 2.3. Steeped grain was milled using a mortar and pestle because the kernel was too small for a waring blender. The slurry obtained was screened through a 75μm British Standard

Sieve (Lab test sieve, Endecotts, Ltd, London UK). The dry starch cake was pulverized into fine powder using a mortar and pestle (Loos *et al.*, 1981).

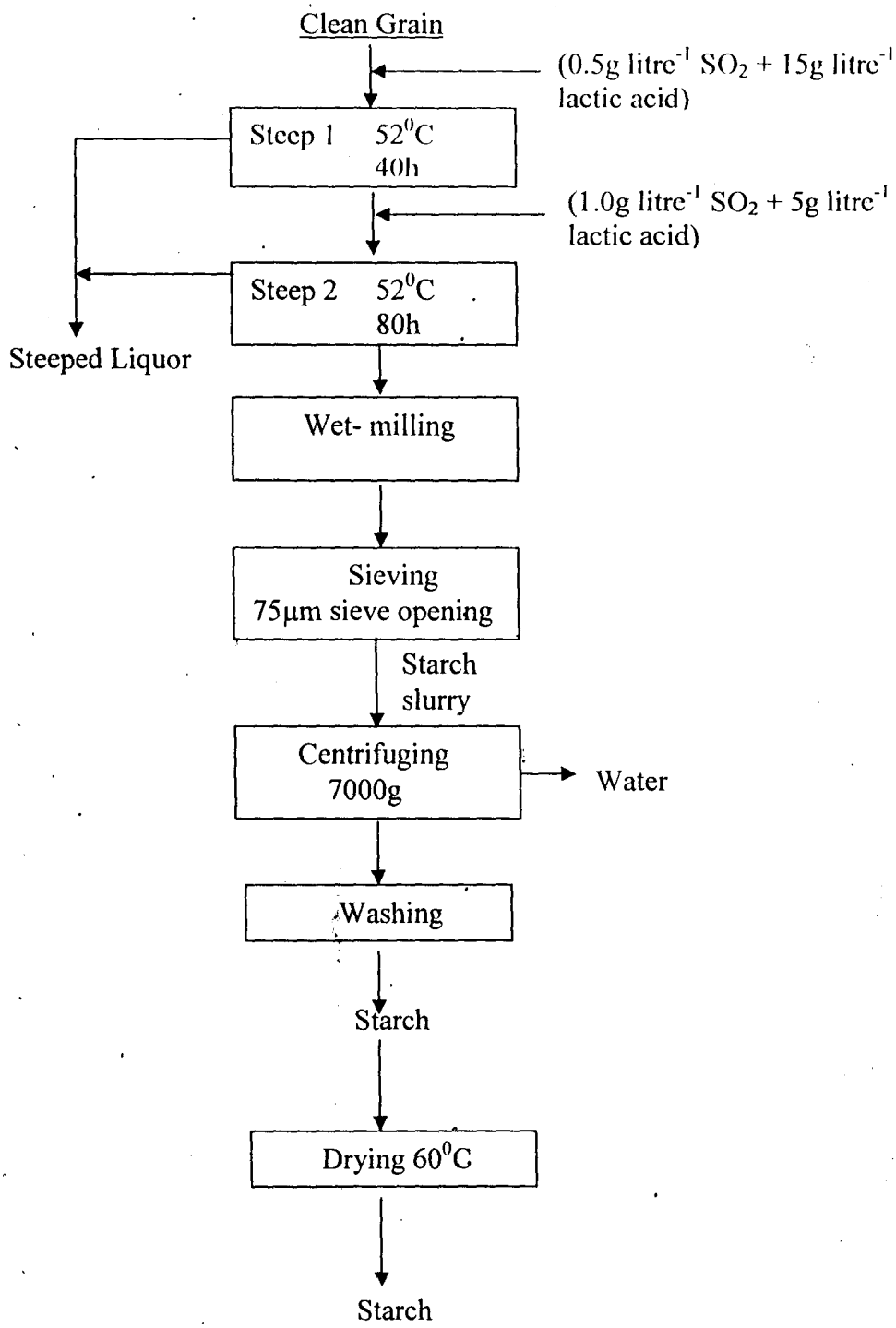

Fig. 2.3: Starch Isolation from Grains of the Cereals *Digitaria exilis* and *Digitaria iburua*
Source: Jideani and Akingbala, 1993.

2.8 Swelling and Solubility of Acha, *Iburua* and Maize Starches

Swelling and solubility of acha, *iburua* and maize starches are presented in Figure 2.4 and 2.5. Acha and Iburua starch samples do not swell as much as maize starch (Fig 2.4) used for comparison. There was no significant difference in the swelling power of starch from the two *Digitaria* species. This is the reflection of the lipid and amylose contents (Table 2.5). Dengate (1984) stated that differences in swelling behaviour appear to be caused by differences in the lipid and amylose contents, together with granule size distribution. The lower swelling power observed for starch from *Digitaria* compared with maize may be due to the greater amylose content (280g/kg) of acha and *iburua* starches compared with the maize starch (231g/kg) and to differences in the molecular arrangement of the starch granules due to species (Leach *et al.*, 1959; Schoch, 1969; Rasper, 1969; Ghlasi *et al.*, 1982).

The characteristic two stage swelling observed in other cereal starches when the temperature of the starch dispersion was raised from 60-95^{0}C (Otterbacher and Kite 1958; Leach *et al.*, 1959) was also observed for acha and *iburua* starches (Fig. 2.4).This is indicative of two sets of bonding forces within the granule that relax at different temperatures (Rasper, 1969 and Loos *et al.*, 1981).

Starch solubility followed the same trend as swelling of the starch slurry in increasing as the temperature of the suspension increased (Fig. 2.4). At 80^{0}C the solubility of the *Iburua* starch was significantly higher ($P \leq 0.05$) than acha starch.

Table 2.5: Chemical Composition (g/kg) and Energy (MJ/kg) Content of Acha and *Iburua*

Taxon	Energy value	Protein	Oil	Crude fibre	Ash	NFE	Amylose	Ca	K	P
Digitaria exilis (Acha)	19.4[a]	62[b]	13[a]	44[a]	10[a]	910[a]	280[a]	0.2	0.2	0.9
Digitaria iburua	19.9[a]	79[a]	13[a]	4.8[a]	14[a]	890[b]	280[a]	0.2	1.8	1.0

a Means in a column with the same following letter are not significantly different ($P \leq 0.05$) by the Duncan's Multiple Range Test.

b Energy values are means of four replicates

Protein (N×6.25), Oil, Crude fibre, Ash, NFE and amylose are means of three replicates on dry wet basis.

Source: Jideani and Akingbaka, 1993

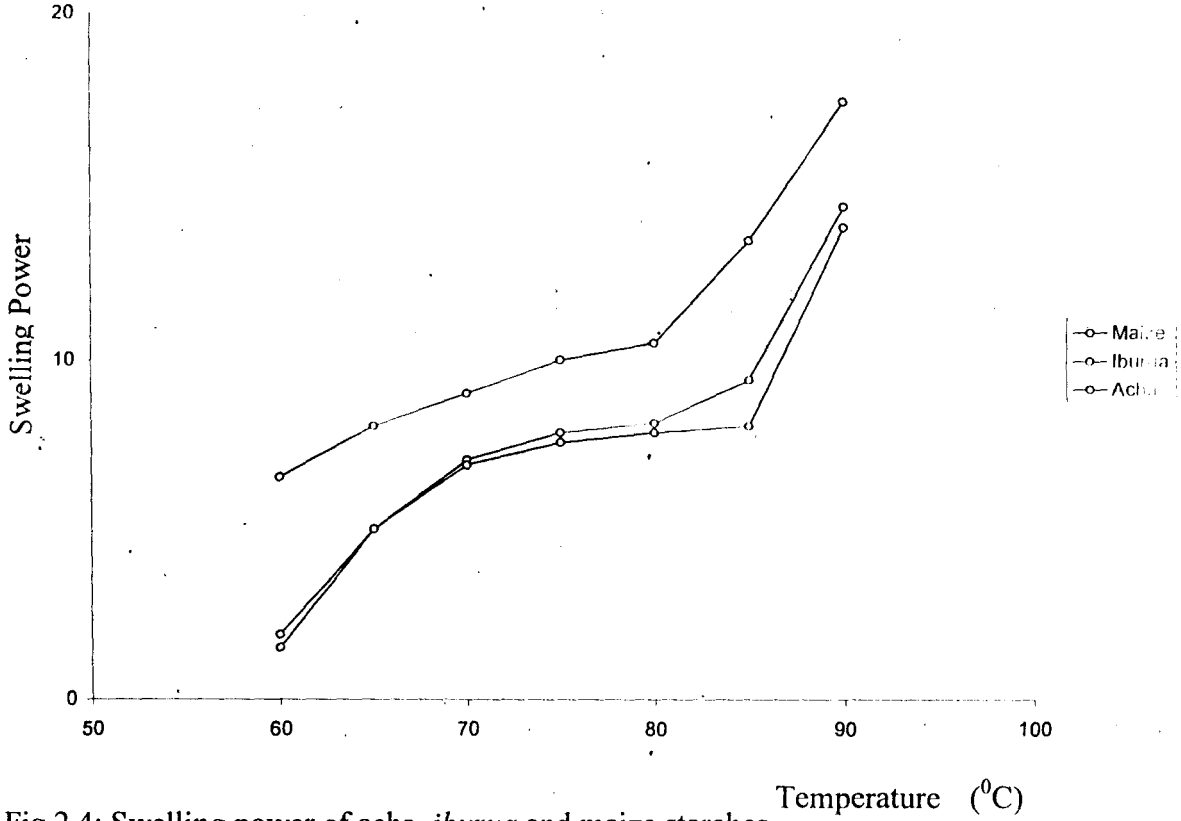

Fig.2.4: Swelling power of acha, *iburua* and maize starches

Source: Jideani and Akingbala, 1993

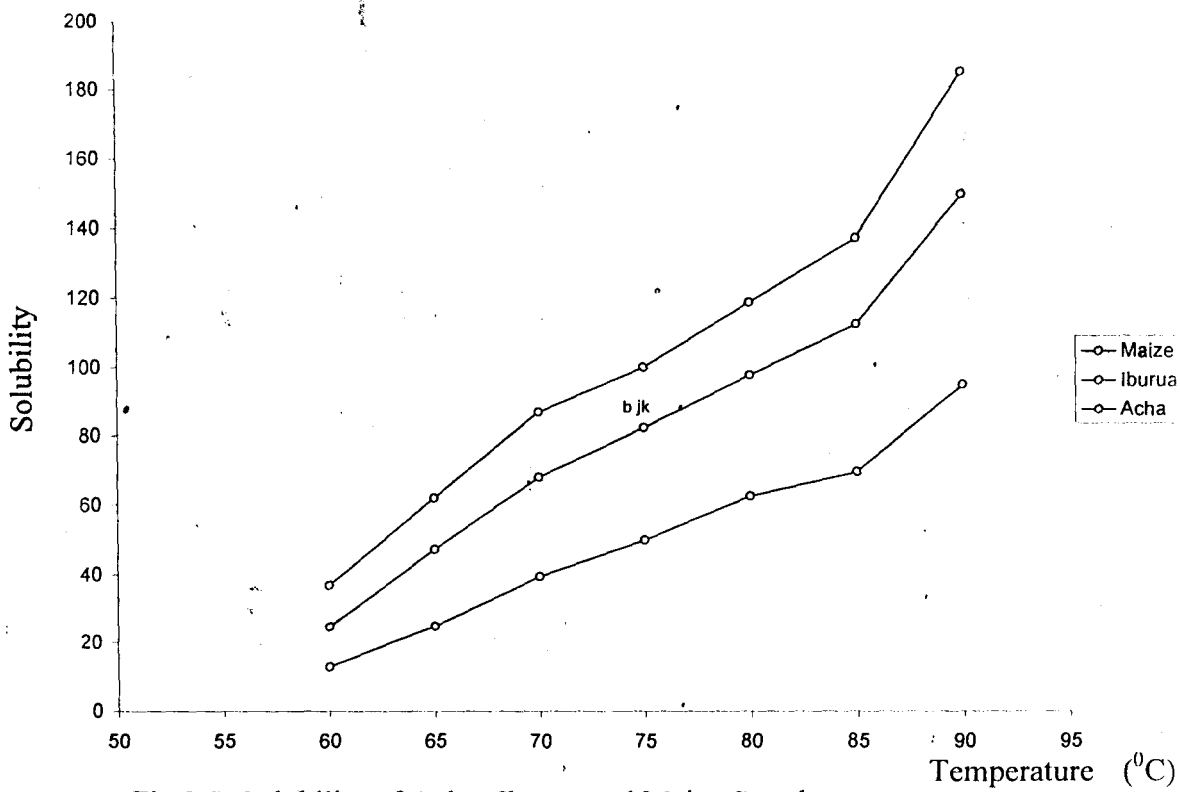

Fig.2.5: Solubility of Acha, *Iburua* and Maize Starches
Source: Jideani and Akingbala, 1993

CHAPTER THREE

3.0 Materials and Methods

3.1 Raw Materials and Sources

Acha (*Digitaria exilis*) and *Durum* wheat samples used for the isolation of protein and determination of cooking effect on their proteins were purchased from Minna Main Market, Niger State, Nigeria. The two cultivated grain varieties *Digitaria exilis* and *Durum* wheat were used as they were purchased.

3.2 Reagents and Instruments

3.2.1 Reagents

The reagents used for the laboratory analysis are:

1. 0.5 N H_2SO_4 (Tetraoxosulphate (VI) acid)
2. Sodium hydroxide solution (NaOH) of which about 450g was dissolved in 1000ml of water.
3. Mixed indicator (Methyl red and Bromocresol green solution)
4. Sodium Sulphate (Kjeldahl catalyst tablet)

3.2.2 Instruments / Equipment

The equipment used for the analysis are:

1. Micro-Kjeldahl nitrogen digestion and distillation apparatus by Gerhardt Bonn Kjeldatherm in Germany, Type; TR.
2. Kjeldahl flask, 500ml.
3. Erlenmeyer flask, 500ml.
4. Burettes
5. Oven

6. Beakers
7. Pipettes
8. Electric hotplate
9. Mucilin cloths/ filter papers
10. Masken tape
11. Electric weighing balance (Analytical balance machine i.e. Adventurer OHAUS) by MELLER in Switzerland. Type; PM 2000 and Serial No; H52764 with the sensitivity of ± 0.001g)

3.3 Experimental Procedures

AOAC (1990) food analysis scheme for estimating crude protein (Appendix A) was followed. The tests and analyses were carried out in the Animal Production Laboratory, Federal University of Technology (FUT), Minna in the presence of my project supervisor Dr. Chukwu., Mr. Saidu Zegi of Agricultural and Bioresources Engineering Department, F.U.T., Minna; Mr. Audu Yohanna of Animal Production Department, F.U.T. Minna; Mr. Lauji M. Ayuba of National Cereals Research Institute (N.C.R.I.) Badeggi, Niger State, Nigeria, and Mr Yakubu Mohammed of (N.C.R.I.) all assisted me in the analyses which took place between June 16, 2008 and July 2, 2008.

3.3.1 Determination of Crude Protein

The samples of acha and wheat were cooked at various ranges of temperature and time and were filtered using mucilin cloths, and finally allowed to dry and then milled. After the milling, about 1g of each sample was carefully weighed on an electrical adventurer analytical weighing balance using Kjeldahl weighing procedure (AOAC, 1990). These were done at different temperatures and times for each sample of acha and wheat.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Results and Analysis

The protein contents of acha (*Digitaria exilis*) and *Durum* wheat are presented in Table 4.1. The variations of protein contents of acha and *durum* wheat at various temperatures and cooking times are shown in Figures 4.1, 4.2, 4.3, 4.4 and 4.5.

Table 4.1: Effect of Heat Treatment on the Protein Content of Acha and *Durum* Wheat*

Treatment	% protein	Durum Wheat treatment	% protein
at raw stage	7.620±0.678	Wheat at raw stage	12.870±0.671
a cooked at 70^{0}C for 10 min	8.260± 0.032	Wheat cooked at 70^{0}C for 10 min	14.868± 0.008
a cooked at 70^{0}C for 20 min	8.290± 0.032	Wheat cooked at 70^{0}C for 20 min	14.868 ± 0.008
a cooked at 70^{0}C for 30 min	8.260± 0.032	Wheat cooked at 70^{0}C for 30 min	14.868 ± 0.008
a cooked at 70^{0}C for 40 min	8.011± 0.032	Wheat cooked at 70^{0}C for 40 min	14.702 ± 0.008
a cooked at 70^{0}C for 60 min	7.847± 0.032	Wheat cooked at 70^{0}C for 60 min	14.702 ± 0.008
a cooked at 80^{0}C for 10 min	8.260± 0.211	Wheat cooked at 80^{0}C for 10 min	14.868 ± 0.012
a cooked at 80^{0}C for 20 min	8.260± 0.211	Wheat cooked at 80^{0}C for 20 min	14.868 ± 0.012
a cooked at 80^{0}C for 30 min	9.086± 0.211	Wheat cooked at 80^{0}C for 30 min	14.702 ± 0.012
a cooked at 80^{0}C for 40 min	9.110± 0.211	Wheat cooked at 80^{0}C for 40 min	14.621 ± 0.012
a cooked at 80^{0}C for 60 min	8.260± 0.211	Wheat cooked at 80^{0}C for 60 min	14.702 ± 0.012
a cooked at 100^{0}C for 10 min	9.251± 1.144	Wheat cooked at 100^{0}C for 10 min	14.042 ± 0.489
a cooked at 100^{0}C for 20 min	9.257± 1.144	Wheat cooked at 100^{0}C for 20 min	14.042 ± 0.489
a cooked at 100^{0}C for 30 min	8.260± 1.144	Wheat cooked at 100^{0}C for 30 min	13.216 ± 0.489
a cooked at 100^{0}C for 40 min	7.220± 1.144	Wheat cooked at 100^{0}C for 40 min	13.110 ± 0.489
a cooked at 100^{0}C for 60 min	7.021± 1.144	Wheat cooked at 100^{0}C for 60 min	12.390 ± 0.489
a cooked at 120^{0}C for 10 min	7.847± 0.075	Wheat cooked at 120^{0}C for 10 min	14.868 ± 1.951
a cooked at 120^{0}C for 20 min	7.840± 0.075	Wheat cooked at 120^{0}C for 20 min	14.868 ± 1.951
a cooked at 120^{0}C for 30 min	7.434± 0.075	Wheat cooked at 120^{0}C for 30 min	13.216 ± 1.951
a cooked at 120^{0}C for 40 min	7.434± 0.075	Wheat cooked at 120^{0}C for 40 min	13.000 ± 1.951
a cooked at 120^{0}C for 60 min	7.234± 0.075	Wheat cooked at 120^{0}C for 60 min	11.564 ± 1.951
ha cooked at 140^{0}C for 10 min	9.086± 1.967	Wheat cooked at 140^{0}C for 10 min	13.216 ± 0.896
ha cooked at 140^{0}C for 20 min	9.086± 1.967	Wheat cooked at 140^{0}C for 20 min	13.216 ± 0.896
ha cooked at 140^{0}C for 30 min	7.847± 1.967	Wheat cooked at 140^{0}C for 30 min	12.803 ± 0.896
ha cooked at 140^{0}C for 40 min	7.102± 1.967	Wheat cooked at 140^{0}C for 40 min	11.220 ± 0.896
ha cooked at 140^{0}C for 60 min	5.782± 1.967	Wheat cooked at 140^{0}C for 60 min	11.564 ± 0.896

*It involves cooking in water at specified temperature and time

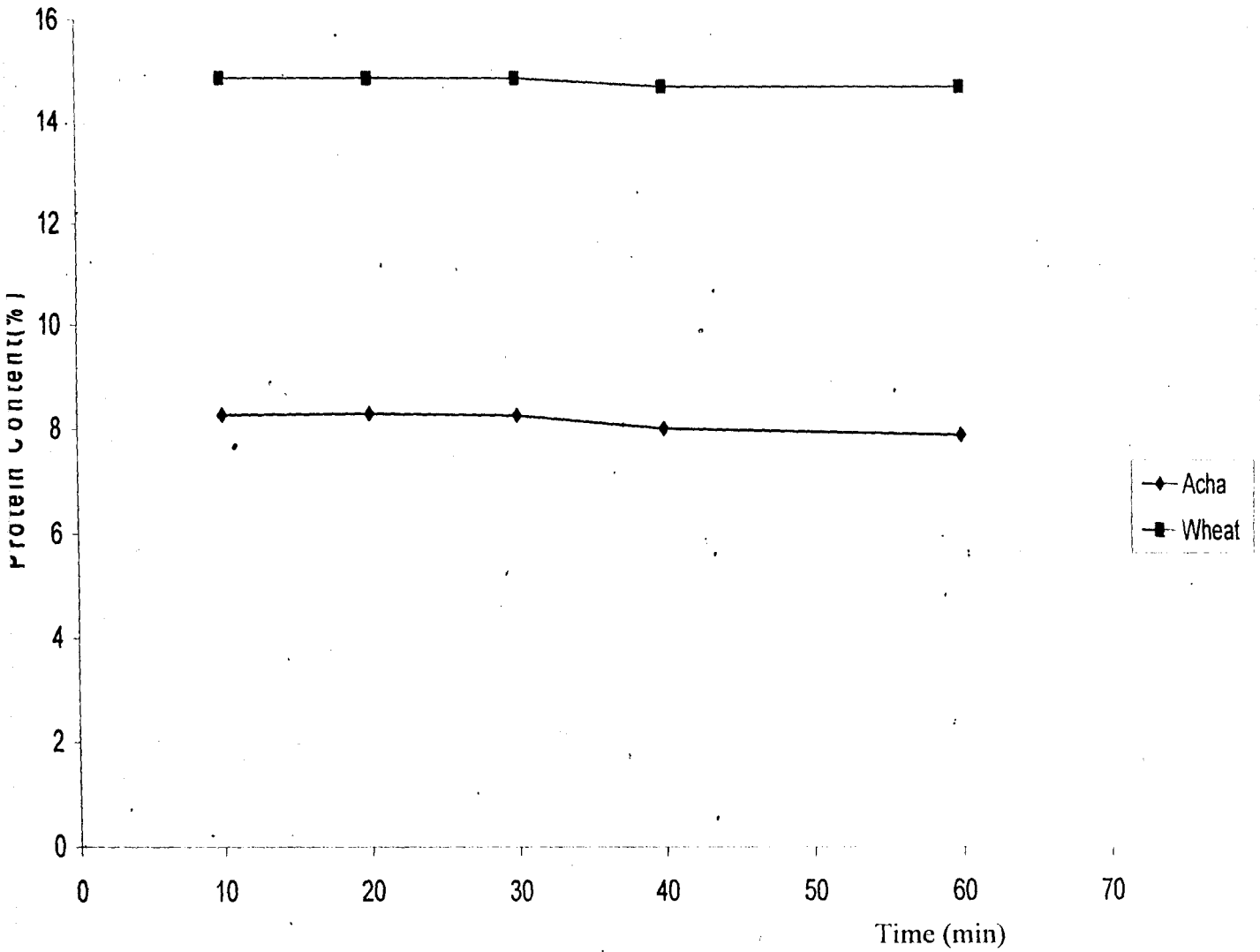

Fig. 4.1: Protein Content of Acha and *Durum* Wheat at 70°C

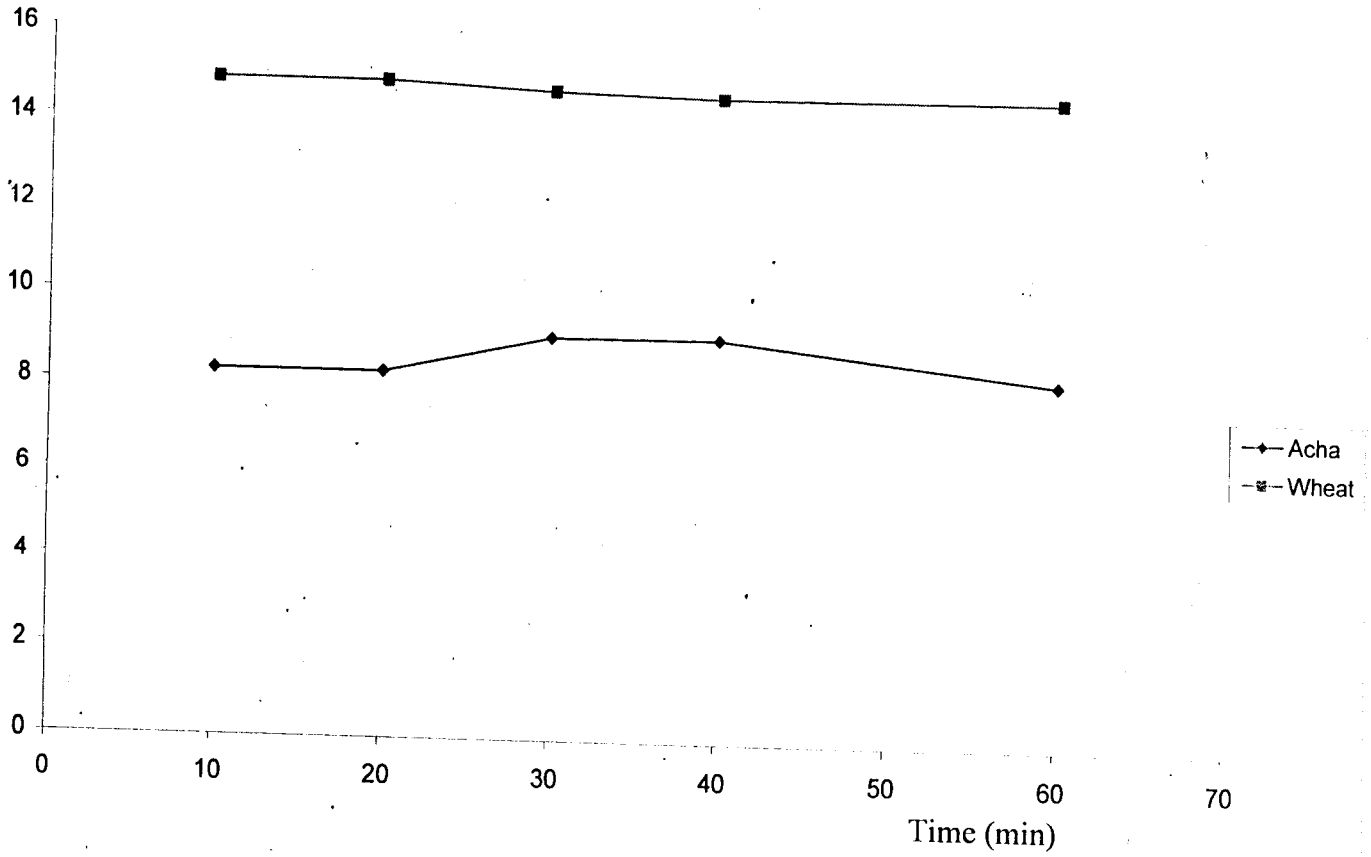

Fig. 4.2: Protein content of Acha and *Durum* Wheat at 80^0C

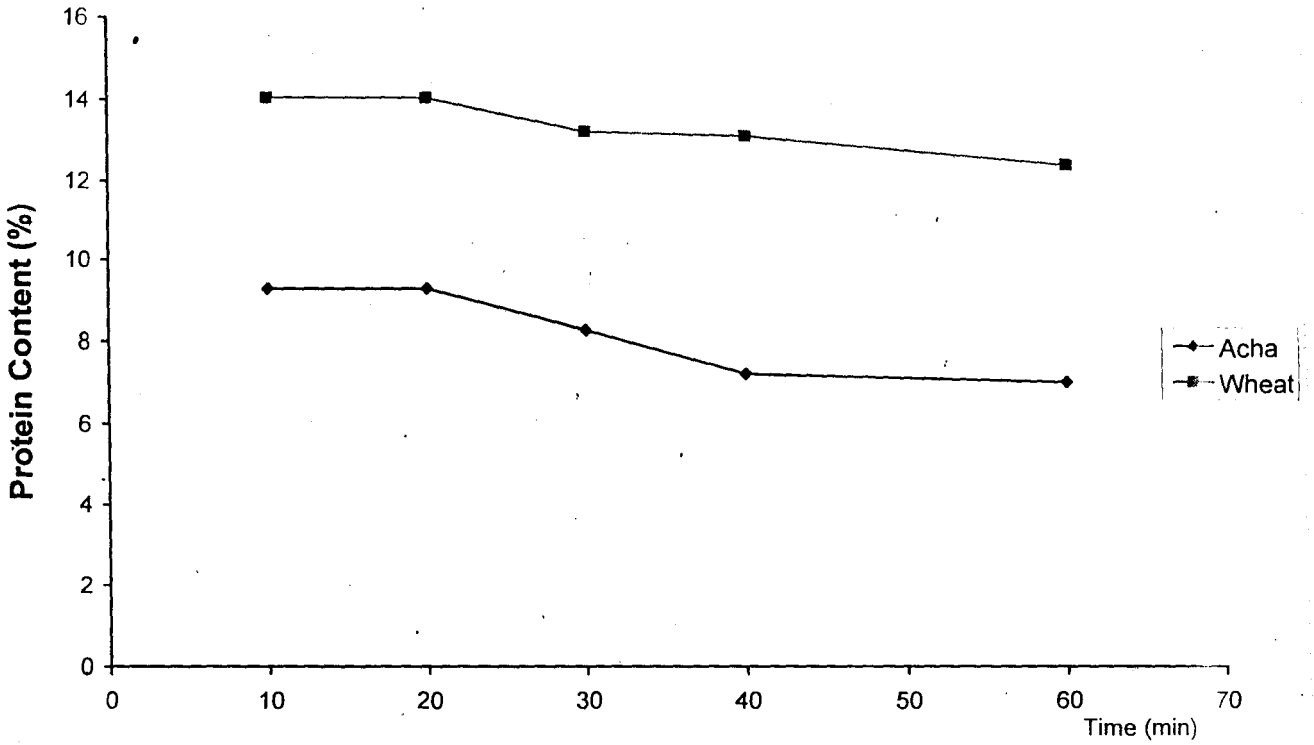

Fig. 4.3: Protein Content of Acha and *Durum* Wheat at 100^0C

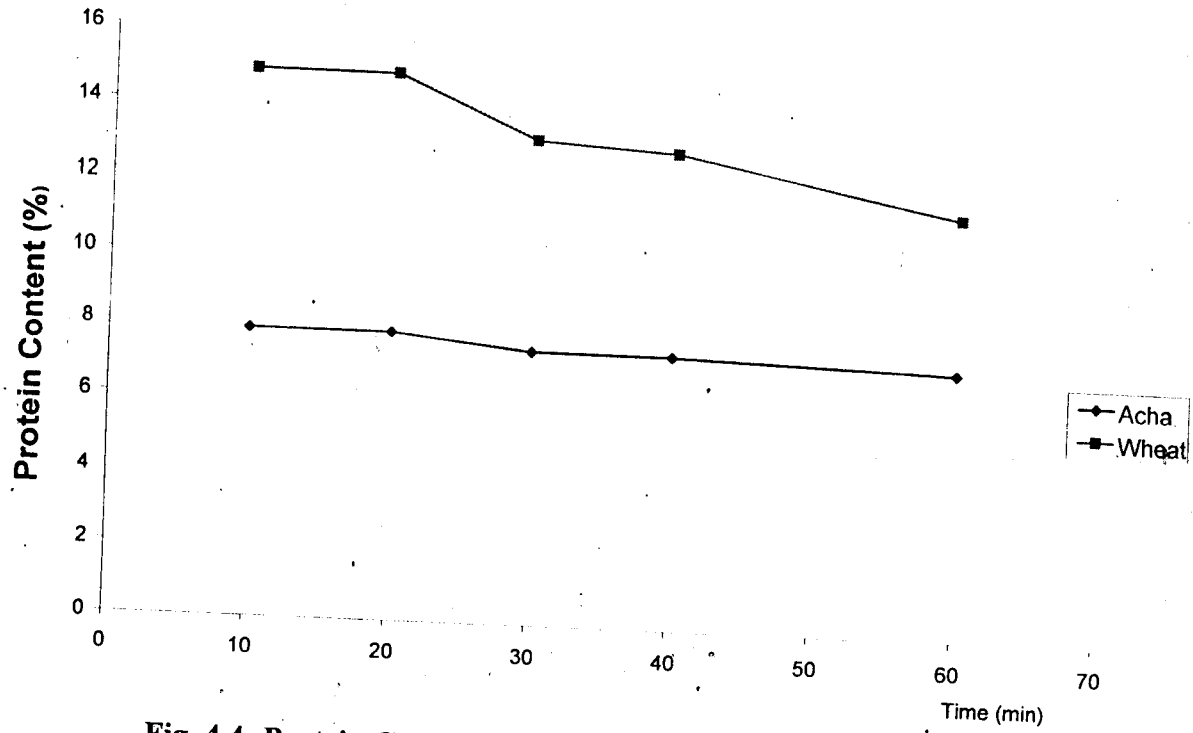

Fig. 4.4: Protein Content of *Acha* and *Durum* Wheat at 120^0C

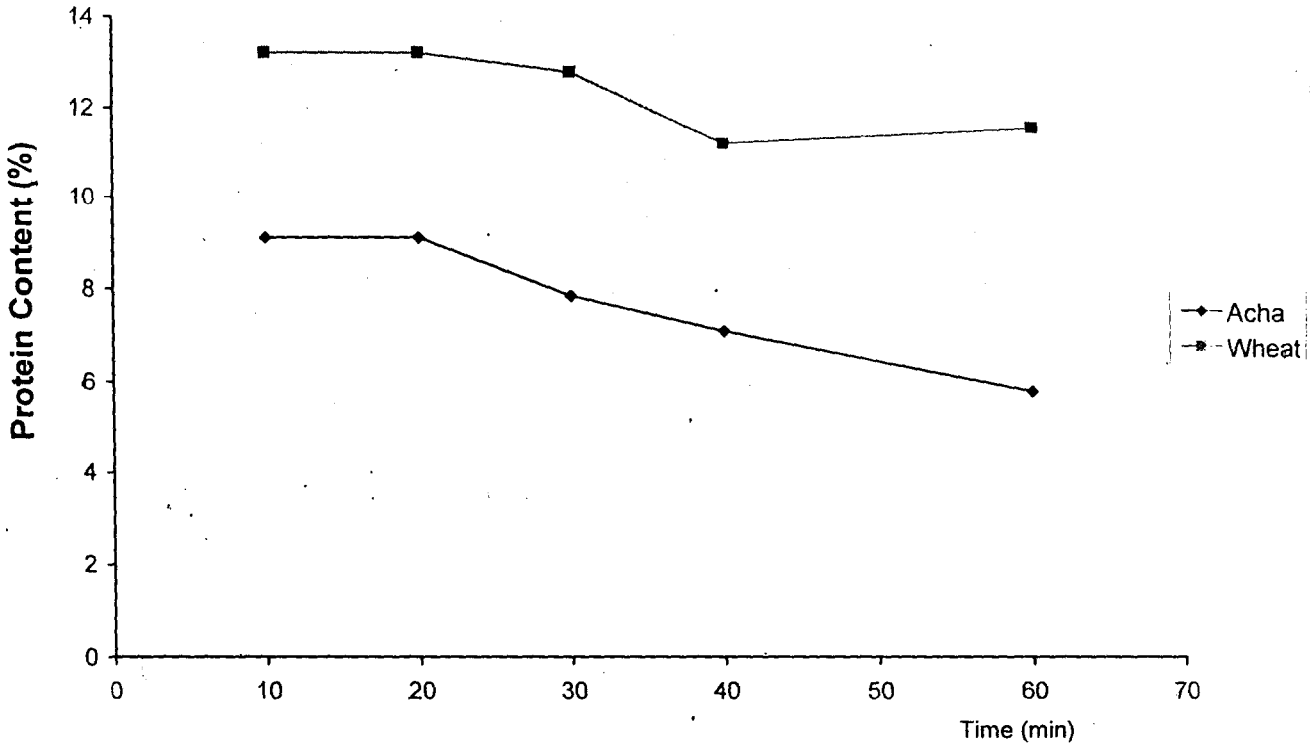

Fig. 4.5: Protein Content of Acha and *Durum* Wheat at 140^0C

4.2 Discussion of Results

Table 4.1 indicates that there are differences in the protein contents of the two cereal grains studied. The protein contents of both acha (*Digitaria exilis*) and *Durum* wheat studied in this work are high when compared with the reported values for other cereal grains of maize, millet, barley, rice and sorghum (Temple and Bassa, 1991). Also the percent protein content of 7.620 ± 0.678 (Table 4.1) for raw acha is higher than the reported value of 7.4 ± 0.31 at raw stage (Jideani *et al.*, 1994) while the value obtained for *Durum* wheat 12. 870 ± 0.671 is lower than the reported value of 14.7 ± 0.12 at the same raw stage (Jideani *et al.*, 1994). It is possible that varietal differences and some anatomical variations could be the reason for the observed differences at the raw stage.

The effects of cooking on protein contents at different temperatures and times (Figures 4.1 to 4.5) are hereby discussed.

1. It was observed that at 70^0C, when acha was cooked between 10 and 60 min, the protein content remained nearly constant (no noticeable difference) and that of *durum* wheat also remained nearly constant (no noticeable difference) as shown in Figure 4.1.
2. At a temperature of 80^0C, the protein content of acha remained constant between 10 and 20 min, increased slightly between 20 and 30 min (actually peaked at 30 min) and remained constant between 30 and 40 min; but between 40 and 60 min the protein content dropped rapidly. For *durum* wheat the protein content remained nearly constant between 10 and 60 min as shown in Figure 4.2.
3. At 100^0C, the behaviour of protein from acha remained constant between 10 and 20 min and then decreased between 20 and 60 min. The values between 40 and 60 min were fairly uniform. The protein content of *durum* wheat remained constant between 10 and 20

min and decreased between 20 and 60 min.

4. At 120^0C, the protein content of acha is such that it remained fairly constant at all times as only a slight difference was noticed. The behaviour of *durum* wheat is such that its protein content remained constant between 10 and 20 min and then decreased sharply between 20 and 30 min. This decrease continued even at 60 min of cooking.

5. At 140^0C, the protein content of acha remained constant between 10 and 20 min and then decreased rapidly between 20 and 60 min while that of *durum* wheat remained constant between 10 and 30 min; decreased between 30 and 40 min and increased between 40 and 60 min.

It was also observed that the percent protein contents obtained when the grains were cooked at different temperatures and times (70 – 100°C and 10 – 30mins for acha) and (70 – 100°C and 10 – 40mins for wheat) are higher than the values for the raw samples of the two cereals (Table 4.1). At higher temperatures and longer cooking times however the protein contents decreased. This is expected since it is known that protein is denatured at high temperatures. More so, the cooking time is appreciably long.

A decrease in protein content may lead to reduced tonnage from acha and *durum* wheat being segregated. This can cause problems in guaranteeing continuity of supply to long-term customers. It can also affect a Commodity Board's ability to penetrate new market areas. Decrease in tonnage from acha and *durum* wheat may also affect the sales of the two cereal crops to the industry and even lower the dietary constituents to both human and livestock. Heat stress has been shown to cause problems in mitochondrial functions and can result in oxidative damage. Activators of heat stress receptors and defences are thought to be related to reaction oxygen species (ROS).

Temperature is one of the most important environmental factors governing plant growth and development. When grown near their optimal temperatures, plants are more likely to reach maximum yield. However, because of the environmental fluctuations, temperatures are often higher than optimum, thus increasing the probability of the grain being exposed to extended periods of supra-optimal temperatures. Such temperatures are detrimental to cereal growth (Badu *et al.*, 1983). The extent of damage caused by heat stress depends on the time of exposure in relation to the stage of the kernel development.

Previous studies have reported protein accumulation in cereals to be slightly affected by heat and water stress (Bhullar and Jenner, 1985). However, this study shows significant effects when heat stress is imposed during the early phase of cooking acha and wheat. The proteins from these cereals are significantly affected by heat stress and protein concentration was also mildly affected by heat. However, protein segregation of wheat classes such as hard red spring wheat and protein segregation of *durum* wheat are not the complete solution to demands from the marketplace. Medium to low protein hard red spring wheat can be used for high quality products such as hearth bread and Asian noodles.

In contrast, low protein *durum* wheat remaining after segregation of high protein material has low market acceptance and lower value because it has limited application outside the pasta industry. *Durum* wheat often is marketed with a minimum protein content guarantee. When protein content is specified, hard vitreous kernel content is less important, but the softer texture of starchy kernels is still a milling factor. The relationship between starchy kernels and *durum* wheat milling performance is complex,

but generally starchy kernels yield less coarse semolina and more flour, reducing *durum* wheat milling potential in markets where coarse semolina is preferred. Wheat growers, who produce wheats in areas where *durum* wheats (Prime Hard and Australian Hard) are segregated, are currently sowing high yielding varieties which have inherently lower protein content than previous varieties (Austran *et al.*, 1986).

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS.

5.1 Conclusion

The result of this study indicates that acha (*Digitaria exilis*) and *Durum* wheat are cheap sources of protein for man and livestock, particularly in dry, infertile areas in the tropics. These grains should be supplemented, however, with protein - rich foods to make a balanced diet due to the fact that their embryo mainly consists of high level of protein and oil with little starch and many other constituents which are essential to human health but which are deficient in other cereals. This agrees with the findings of Temple and Bassa (1991). The properties of acha (*Digitaria exilis*) and *Durum* wheat also make these grains to be good candidate for use as edible grain and as raw material for several domestic and industrial purposes like making beer, alcoholic drinks and other applications. Acha and *Durum* wheat are known to be easy to digest and they are traditionally recommended for children, old people who cannot digest other cereals, sick people and for people suffering from diabetes or stomach diseases. Local pharmacists also recommend acha for people who want to lose weight due to its protein quality (methionine) (Chukwu and Abdulkadir, 2008).

The anti-physiological factors are destroyed in about 20 minutes, which results in an increase in protein quality of acha (9.257±1.144) when cooked under the temperature of 100^0C and that of *durum* wheat (14.868 ± 1.951) destroyed at about 10 – 20 minutes under the temperature of 120^0C as shown in Table 4.1. In view of this, maximum protein content of acha and *durum* wheat can be said to be obtained under the temperature of 100^0C for 20 minutes and 120^0C between 10 – 20 minutes respectively. However,

excessive cooking time causes a progressive decrease in nutritive value of acha and *durum* wheat due to the loss of Lysine. Protein content has a greater influence on overall processing quality than any other single factor. While the environment is the major determinant of the actual protein level achieved, the variability between wheat varieties in their capacity to accumulate protein is also important.

Recommendations

The following recommendations have been made.

1. Since laboratory analysis has indicated that acha (*Digitaria exilis*) and *Durum* wheat are parts of the cheapest sources of protein, it is therefore necessary to recommend these grains for lactating women and diabetic patients by medical experts and even the local pharmacists.
2. It is further recommended that food and processing industries adopt the techniques used in this study for extracting proteins from cereal grains. This is because it is faster without compromising the nutritive values of the agricultural product.

REFERENCES

Abdulkadir, J. A. (2007). Analysis of the nutritional content of acha (*Digitaria exilis* and *Digitaria iburua*).Unpublished B. Eng. Project, Department of Agricultural Engineering, Federal University of Technology, Minna, Nigeria. pp. 4 – 26

Akingbala, J. O. (1982). Effect of physicochemical properties of sorghum starch and endosperm on the quality of a traditional African Food. PhD dissertation. Texas A and M, University college station, TX, USA.

Anon. (1970). New protein foods from traditional process. *Nutrition Review* **38**:9-11.

AOAC (1990). Association of Official Analytical Chemist. In Official Method of Analysis: 15th Edition. Washington DC, USA. pp. 537- 544

Austran, J.C., Abecassis, J. and Feillet, P. (1986). Statistical evaluation of different technological and biochemical tests for quality assessment in durum wheats. Cereal Chem. 63:390-394.

Badu, A. B., Hunter, R. B. and Tollenaar, H. (1983). Effect of temperature during grain filling on whole plant grain yield in maize. Can. J. Plant Sci. 63: 357 – 363.

Bhullar, S. S. and Jenner, C. F. (1985). Differential responses to high temperatures of starch and nitrogen accumulation in the grain of four cultivars of wheat. Aust. J. Plant Physiol. 12: 363 – 375.

Bakere, B. S., Allen, D.J., Thottappilly, G. (1998). The Pathology of food and pasture legumes. CAB international pp. 179 – 265

Bento, J., Haffner, S. M. and Lehto, *S.* J. (1986). Association of Protein Tyrosine Phosphatase-N1 Polymorphisms. *American Journal Epidemiol* 123:504–516.

Bodgan, T. (1977). Common Toxic compounds in legumes. *Biomedical and Life Sciences* 42:120 - 126

Bonjean, A. P., and W.J. Angus. (2001). The World Wheat book: a history of Wheat Breading. Lavoisier publication. Paris, France. pp.1131.

Brink, M., Belay, G. and Lemmens, R.H.M.J. (2006). Plant Resources of Tropical Africa 1 Cereals and Pulses Prota and Backhuys publication. Wageningen,Netherlands. pp. 54-200

Carbiener, R., Jaeger, P., and Busson, F. (1960). Etude de la Fraction protidique de la grain de Fonio (*Digitaria exilis (Kippist)* stapf): une proteine exceptionnellement riche en methionine. Ann Nutrition Allmentation 14 (2) 165 – 169.

Chukwu, O. and Abdulkadir, J. A. (2008). Proximate chemical composition of Acha (*Digitaria exilis* and *Digitaria iburua*) Grains. *Journal of Food Technology* 6 (5):214 – 216.

Cisse, P. O. (1975). Nutrition and physical performance. In "Nutrition and the World Food Problem", Basel: Karger Press, p 63.

Clawson, A.R. and Taylor, A. J. (1993). Chemical changes during cooking of wheat. *Food chem*. 47 337 – 343

Counihan, C. and Van Esterik, P. R. (1997). The culinary Triangle in food and culture. *http:www.wikimedia.com*

Dachi, H., Matsumura,H., Takano, K., Inoue, T., Mori, K and Sasaki, T. (1995). Two-Liquid Hanging-Drop Vapor-Diffusion Technique of Protein Crystallization. *Japan Journal of Applied Physics* 43: L79-L81

Dachi, S. N. (2000). The effect of different rates of NPK and Organo- mineral fertilizers on the growth and yield of acha (*Digitaria exilis*) kippis stapf in South West Nigeria.

David, S., Gary, M., Tom, H., Kelvin, M. and Pamela, C. (2004). Department of Agriculture market Access program (MAP) grant made available to wheat marking centre, Inc. Portland, Oregon USA.

Dengate, H. N. (1984). Swelling pasting and gelling of wheat starch. In Advances in Cereal Science and Technology. Vol. VI, ed pomeranz Y. AACC Inc, St paul, MN, USA. pp 49 -82.

de Lumen, B. O., Beekar, R. and Reyes, P. S. (1968). Legumes and a cereal with high methionine/ cysteine contents. *J. Agric. Food chem.* 34: 361 – 364.

de Lumen, B. O., Thompson, S. and Odegard, J . W. (1993). Sulphur amino acid – rich proteins in acha (Digitaria exilis) a promising underutilized African Cereal. *J. Agric. Food Chem.*, 41, 1045 – 7.

Douglas, D. B, Lark, P. C, Stephen R. C. and William F. B. (1983). Crop Science and Food Production. Gregg Division McGraw – Hill Book Company Inc. pp. 1- 368

Ewart, J. A. D. (1990). Comments on recent hypothesis for glutenin. *Food chem.* 38: 159 – 169.

FAO. (1978). Physical Activity: Impact on Protein and Amino Acid Metabolism and Implications for Nutritional Requirements. World Health Organization (WHO) Tech. Report Series No. 522, Geneva: World Health Organization.

Foster, L., Lindemann, M. D., Medade, R. J., Hanke, H. L., Cornrlius, S. G. and Rust, J. W. (1961). Evaluation of high oats as a replacement for corn in diets feed to

growing finishing swine. *Journal of animal Sci* 56: 853 – 857

Ghlasi, K., Hoseney, R. C., and Varriano. M. E. (1982). Gel–atinisation of wheat starch I. Execess water systems. *Cereal chem.* 59 81 - 85

Halm, M., Lillie, A., Sorensen, A. K. and Jakobsen, M. (1971). Microbiological and Protein content of raw maize. *Journal of Food Sciences* 12:32 – 40.

Hamaker, B. R., Kirleis, A. W., Mertz, E. T., and Axtell, J. D. (1986). Effect of cooking on protein profiles and in–vitro digestibility of sorghum and maize, *J. Agric food chem.* 34 617 – 649.

Harinaraya,A. T., (1986). Plant for arid lands. Proceedings of the new international conference on economic plants for arid lands. Allen and Unwin, London, United Kingdom. Pp. 69 – 86.

Hist, H. W., Vavak, D. L., Satterlee, L. D., Miller, G. A. A. (1977). Multienzyme technique for estimating protein digestibility. *J. Food Sci* 42: 1269 – 1273

Jideani, A. I., (1990). Acha (*Digitaria exilis*) the neglected cereal, Agric Int., 42 (5): 132 – 134.

Jideani, I.A. and Akingbala J.O. (1993). Some physicochemical properties of acha (*Digitaria exilis stapf* and *iburua* (*Digitaria iburua Stapf*) grains. J. Sci. Food Agric., 63: 369–374.

Jideani, A.I., Owusu, R.K and Muller, H. G, (1994). The Effect of Cooking on Protein from Acha (*Digitaria exilis*) and *Durum* Wheat. *J. Sci . Food Agric.* Sussex. John wily: &: Sons 65 (4) pp. 464 – 476.

Johnson, C. (1958). The Limiting Amino Acids in Soybean Protein. *Science* 211:448 455.

Lantican, H. (1999). Wheat production and improvement in the Sudan. Wad Medani, Sudan. ICARDA, Aleppo, Syria. pp. 262-67

Leach, H.W:, McCowen, I. D. and Schoch, T. J. (1959). Structure of the starch granule, Swelling and solubility pattern of various starches. *Cerael chem.* 36 534 - 544

Loos, P.J. Hood, L.F., and Graham, H. D. (1981). Isolation and Characterization of starch from bread fruite. *Cereal Chem* 58 282 – 286.

National Research Council (NRC) (1996), Lost Crop of Africa, Vol. 1, Grains National Academic Press, Washington D.C., pp 3-6, 59-72,251-272, 360.

Oates, W. E. Katherine, M. N., Krause, R., Jones, L. and Colby, R. H. (1959). Rheopexy of synovial fluid and protein aggregation. *Journal of Royal Society* 711: 53

Omen, C. H. and Bushuk, W. (1970). Nature of proteins in triticate and its parental species 1. Solubility characterization and amino acid. Composition of endosperm proteins. *Can J. Plant Sci* 50: 9 – 14

Otterbacher, T.J. and Kite, F. E. (1958). The Milo starchs. *Bakers Digest* 47 44– 48.

Padulosi, S. K., and Hammer, J. H, (1996). Hulled wheat. Promoting the conservation and use of underutilized and neglected crops. International Plant Genetic Resources Institute. Rome, Italy.

Porteres, V. (1955). Food safety preparation and storage. Tips cooperative Extension, College of Agriculture and Life sciences, the University of Arizon

http://en. Wikipedia. org/wiki/Cooking

Purseglove, J. W. (1985). Volatile flavour compounds of cooked acha. *J. Food Chem* 14:170 – 179.

Rachie, K. O. (1974). The Millets and Minor Cereals. (A Biblography of the World Literature on Millets Pre. 1930 and 1964- 69: and of All Literature on Other Minor Cereals). The Scatecrow Press Inc. Meluchen. NJ. USA.

Rasper, V. (1969). Investigation on Starches from major starch crops grown in Ghana. H.swelling and solubility patterns. Amyloclastic susceptibility. *J. Sci Food Agric* 20: 642 - 646

Rooney, G. (1961). Experimental coconut protein products. *Journal of American Oil Chemists' Society* 56(3):79 – 85.

Rooney, I. W., Kirleis, A.W., Murphy, D.S., (1986), Traditional food from Sorghum: their production, evaluation and nutritional value, Adv. Cereal Sci. Tech. pp.317-53

Routledge, P. (1997). Amino acid metabolism in exercising man. *J.Food Sci.*111(8):629 638.

Schoch, T.J. (1969). Mechano Chemistry of starch *starch chem.* 32 109, 166.

Stanfield, R. L. (1970). Regulation and significance of amino acid metabolism. Protein *Sci* 12:1960–1970.

Steel, R. (1976). Milk Protein/Stainless Steel Interaction. *J. Nutr.*, 26(2):363 – 381.

Tannenbaum, S. (1974). Industrial Processing In: *Nutrition in processed Food Proteins.* Publicating Science Group Inc, Action, MA, USA.

Temple, V.J. and Bassa, J. D. (1991). Proximate chemical composition of acha (*Digitaria exilis*) grain. *J. Sci food Agric* 56: 561 – 563

Wikipedia. (2008). Retrived from *"http://en. wikipedia. org/wiki/ wheat"* on 6/6/2008

the chemical changes. Nitrates and Nitrites are not determined by this procedure. Kjeldahl method is a volumetric method producing $(NH_4)_2SO_4$ by acid digestion of sample from alkaline digest, ammonia is distilled off, collected as Boric complex and estimated.

The Kjeldahl digestion is usually performed by heating the sample with H_2SO_4 containing substances which promote oxidation of organic matter by increasing the boiling point of the acid (K_2SO_4 or Na_2SO_4) and Se or Cu which increase the state of oxidation of organic matter. These reagents here are referred to as digestion catalyst. it is necessary to digest the sample for a certain period until you obtain a clear solution to ensure accurate results.

Procedure

Digestion (Stage 1)

1a. 1g of wet sample was carefully and accurately transferred into 50ml kjeldahl flask, and 20ml of concentrated tetraoxosulphate (VI) acids (H_2SO_4) was added to the sample with one kjeldahl catalyst tablet.

1b. About 0.5g of dry sample was also weighed into 50ml micro-kjeldahl flask, and 5ml of concentrated H_2SO_4 with half kjeldahl catalyst tablet and labeled W_1

2. The flask was placed in an inclined position and heat was applied to it for about 15minutes, below the boiling point, the process was increased to medium heat for about 30minutes again and finally at high heating until digested. The flask was rotated at intervals until the digest is clear (light green or grey white), the heating was continued for few minutes after this oxidation stage is completed to ascertain complete digestion.

Equation for the reaction (Distillation)

$(NH_4)_2SO4 + 2NaOH \longrightarrow 2Na_2SO4 + NH_3 + 2H_2O$

$NH_3 + H_3BO_3 \rightleftharpoons NH_4 + H_2BO_3.$

$$Nitrogen\ (\%)in\ the\ Sample = \frac{Title\ Value\ (ml) \times 0.014 \times \left(\frac{V_1}{V_2}\right)}{Weight\ of\ Sample} \times 100$$

Crude protein content (%) = 5.90 × N, where N is nitrogen %

Where 5.90 is the standard factor for protein conversion in cereals

The calculation which resulted into the Table 4.1 shown above is given below:

Specimen calculation

TV= Titre value (control titre (T)) = 1.0, for 70^0C cooked for 10minutes

M_A = Molarity of Acid used = 0.1 of HCl

V_1 = Initial volume of digest = 100ml

V_2 = Volume of digest used = 10ml

G = weight of sample = 1g

Formula for calculating % protein:

$$\%\ N = \frac{TV \times M_A \times 0.014 \times \left(\frac{V_1}{V_2}\right)}{Weight\ of\ Sample\ in\ (g)} \times 100$$

$$\%\ N = \frac{1.0 \times 0.1 \times 0.014 \times \left(\frac{100}{10}\right)}{1} \times 100$$

% N = 1.4

% Nitrogen in the sample =1.4

Therefore crude protein (%) = 5.90 × Nitrogen (%)

= 5.90 × 1.4

= 8.26 %

Therefore 8.26 % is the percent crude protein for acha cooked at 70^0C for 10 minutes