KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

SCHOOL OF GRADUATE STUDIES

COLLEGE OF SCIENCE

FACULTY OF BIOSCIENCES

DEPARTMENT OF BIOCHEMISTRY AND BIOTECHNOLOGY

INNOVATIVE METHODS FOR PROCESSING SNAIL (*Achatina achatina*) MEAT POWDER OF HIGH MICROBIOLOGICAL AND SENSORY QUALITIES

BY

SAMUEL ANTWI

AUGUST, 2009

INNOVATIVE METHODS FOR PROCESSING SNAIL (*Achatina achatina*) MEAT POWDER OF HIGH MICROBIOLOGICAL AND SENSORY QUALITIES

BY

SAMUEL ANTWI

DEPARTMENT OF BIOCHEMISTRY AND BIOTECHNOLOGY,

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,
KUMASI, GHANA

AUGUST, 2009

A THESIS SUBMITTED TO THE DEPARTMENT OF BIOCHEMISTRY AND BIOTECHNOLOGY, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, GHANA IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE FOOD SCIENCE AND TECHNOLOGY

INNOVATIVE METHODS FOR PROCESSING SNAIL (*Achatina achatina*) MEAT POWDER OF HIGH MICROBIOLOGICAL AND SENSORY QUALITIES

A THESIS SUBMITTED TO THE DEPARTMENT OF BIOCHEMISTRY AND BIOTECHNOLOGY, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, GHANA IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE FOOD SCIENCE AND TECHNOLOGY

Certified as the original work of the author, SAMUEL ANTWI

…….

BY

PROF. J. H. OLDHAM ……..

(SUPERVISOR)

ABSTRACT

A new method of purging the snail in addition to three drying methods, namely smoke-drying, gas-drying and solar-drying were chosen for this work. Proximate, microbiological and sensory analyses were conducted on dry snail meat powders from the three drying methods. The proximate analyses showed that there were no significant difference ($p > 0.05$) in the values of protein, ash and moisture using the three dryers. However, significant differences ($p > 0.05$) were recorded in the values of fat, total carbohydrate and energy content of the dry snail meat powders produced from the three dryers. The smoke dried samples had the least number of microoganisms with 5.15×10^4 cfu/g and 6.64×10^4 cfu/g for bacteria and mold respectively at the end of the thirty – week storage period. The smoke dried samples had the best sensory qualities and were most preferred in terms of aroma and colour. From the results obtained, a combination of purging and smoke drying using smoke generated from sawdust and charcoal from hard wood, in addition to hygienic handling and milling are the most innovative methods for processing snail meat powder to obtain products of high microbiological and sensory qualities.

TABLE OF CONTENTS **PAGE**

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENT

To the Almighty God I say thank you.

My special thanks go to the Centre for Biodiversity and Utilization Development (CBUD) of KNUST for partially sponsoring this project.

Sincerest gratitude goes to my able supervisor Prof. J. H. Oldham of Biochemistry Department, KNUST for the precious advice and invaluable time and effort he devoted to critically scrutinize my work. Appreciation is also expressed to Mr. E.Y.A. Amankwaa of the Department of Biochemistry for his advice on the use of some of the instruments and the dryers used for the work. I also appreciate the selfless assistance offered me by Laboratory Technicians of the Department of Biochemistry.

Last but not the least my profound gratitude goes to my lovely wife, Mrs. Grace Antwi for her support and encouragement throughout the project.

CHAPTER ONE

INTRODUCTION

1.1 Background study

The major source of animal protein comes mainly from livestock in the form of poultry, beef, mutton and pork (Fleck, 1976). However, in Ghana these major sources are being decreased by persistent drought, diseases, high cost of feed, primitive animal husbandry techniques as well as low productivity of local animal breeds. The increasing growth of human population together with the rising standard of living has also placed great pressure on the existing sources of animal protein. There is therefore the need to consider non-conventional source of meat protein such as land snail meat.

Snails are the largest group of molluscs constituting the largest animal group after arthropods (Yoloye, 1984). They have soft bodies and lack skeleton. They are also classified under the class gastropoda because they appear to walk on their belly.

Ghana is the abode of four main kinds of snails known as the African giant snails, with the commonest being *Achatina achatina* locally known as 'nwapa'.

Land snail meat is consumed in many countries in the world and it is considered as a delicacy for the rich. Snail meat has a high protein content and low in fat. The meat has over 20 different amino acids including the eight essential amino acids required by man and contains calcium, phosphorus, as well as selenium, boron, zinc and other micro elements. Because of its nutritional value, nutritionists recommend snail meat for astronauts and athletes (Fagbuaro *et al*., 2006).

Snails have a long-standing and widespread importance as a source of human food. In Ghana, the giant African land snail (*Achatina achatina*) is the most popularly consumed snail. However, the seasonality of the supply of snails limits their use on continuing basis without processing the meat. During the dry season, snails aestivate and become very scarce and expensive but in the rainy season they are abundant and cheap. During this aestivation period, the aperture of the snail is temporarily closed by a calcified material known as epiphragm which is a whitish, fragile material (Nisbet, 1974). During aestivation, the snails bury themselves in the soil or hide beneath stones in order to avoid direct solar radiation (Schmidt-Nielsen *et al*., 1971). When the rain falls the epiphragm breaks and very cold water stored before aestivation pours out of the aperture (Ajayi *et al*., 1980), and the snails emerge to eat the new plant growth and the soft soil (Ajayi *et al*., 1980; Odaibo, 1997). Though snails have been acclaimed to be rich in protein and other essential nutrients for good health snails are not regular in the diet of many Ghanaians.

Many countries have large international market for snails and a great deal of them exports snails for foreign exchange. Among these are China, France, Italy and many other European countries (Elmslie, 1982). Available data show that Ghana exported 620 kg of snails in 1994 to the Netherlands and 1,050 kg to the U.S.A (Ablordeppey and Asamoah, 2003). The price of the giant African land snail is relatively low on the international market, about one-third the price of the European species. This is because the meat of the African species is considered rubbery and the shell is less suitable for presentation (FAO, 1986). Thus, processing the snail meat into powder and dried snail meat are an alternative to overcoming these problems as well as adding value to the giant African snail meat.

1.2 Statement of Problem

Local methods employed in processing and packaging snail meat powder expose them to microbial and environmental contamination (Tettey *et al*., 1997). Analysis conducted by the Department of Biochemistry and Biotechnology of Kwame Nkrumah University of Science and Technology (KNUST) on snail meat powder samples produced by the Centre for Biodiversity Utilization and Development (CBUD) of KNUST showed that the samples were microbiologically unwholesome (CBUD contract No: CBUD/AFC/017, unpublished). Engmann (2005) reported that smoke dried snail meat samples had better sensory attributes compared to solar dried samples. However, the microbiological quality was very low. This calls for more research into innovative processing methods of drying snail meat to give products of high microbial and sensory qualities.

The Department of Biochemistry and Biotechnology of KNUST has improved drying facilities by designing and building new solar dryer, gas dryer and smoke dryer which were not used by previous researchers. These new methods of drying together with a new method of purging the snails are expected to give dry snail products of better sensory and microbiological qualities.

1.3 Justification

There is a need for improved processing methods for dried snail meat and snail meat powder because of the nutritional and health benefits associated with snail meat consumption. Snail meat powder could serve as a cheap source of animal protein for preparing food for weaning babies, particularly, in rural forested areas where snails are available during rainy season and can be picked from the wild. Interestingly, these areas

have high incidence of kwashiorkor as a result of protein malnutrition (Asibey, 1986). Snail powder can also be used for the preparation of many local food products such as 'shito'. Shrimp powder is currently being used in preparing 'shito' which is quite expensive.

Processing snail meat into powder will also add value to the giant African snails and thus increasing its demand on the international market. The fresh giant snails have low market value in Europe because of its rubber-like texture (FAO, 1986).

1.4 Main Objectives

The main objective of this study is to use solar, smoke and gas dryers to dry fresh snail meat and to produce snail meat powder of high microbiological and sensory qualities.

1.5 Specific Objectives

1. To study the effect of the drying systems on the proximate values, microbiological and sensory qualities of the snail meat powder.
2. To study the shelf life of the powders produced from the three dryers over a period of thirty weeks.

CHAPTER TWO

LITERATURE REVIEW

2.1 Importance of protein to human nutrition

Dietary proteins are compounds that build and repair body tissues, from hair and fingernails to muscles (McKee, 1996). In addition to maintaining the body's structure, proteins speed up chemical reactions in the body, serve as chemical messengers, fight infection, and transport oxygen from the lungs to the body's tissues. Although proteins provide 4 calories of energy per gram, the body uses protein for energy only if carbohydrate and fat intake is insufficient (McKee, 1996).

Proteins are made of smaller units called amino acids (Lehninger, 1987). Of the more than 20 amino acids our bodies require, nine cannot be made by the body in sufficient quantities to maintain health. These amino acids are considered essential and must be obtained from food (Lehninger, 1987).

Animal proteins, found in such food as eggs, milk , meat , fish, poultry and snails are considered complete proteins because they contain all of the essential amino acids our bodies need. Plant proteins found in vegetables, grains and beans lack one or more of the essential amino acids. However, plant can be combined in the diet to provide all of the essential amino acids (Lehninger, 1987).

2.2 Nature of Snails

Land snails have no physiological means of controlling intake or loss of moisture other than sealing themselves in their shells and are relatively intolerant of extreme cold or heat

and dry conditions (Schmidt-Nielsen *et al.*, 1971). Land snails have evolved physiological responses to deal with cold (hibernation) and heat or drought (aestivation) that allows them to survive extended periods without taking in nourishment. This combined with the fact that they are also hermaphrodites and can on occasion self fertilize, means that land snail evolution has been rather slow and polymorphism is quite common.

Snails belong to the phylum of animals called molluscs which are invertebrate animals with an exoskeleton. They belong to the class gastropoda because they appear to walk on their stomach. The gastropods include snails and slugs of which there are about 40,000 species or 80 % of all living molluscs (Yoloye, 1984). They are found in most part of the world on land, in the sea or in fresh water. The largest and most striking examples are found in the tropical African countries.

The European edible snails were in the past a popular food all over Europe, but today it is an expensive luxury. It has been virtually wiped out as a pest of vineyard and parasite vectors, but still extensively farmed (Muller, 1988).

2.3 The giant African snail

Giant African Snail is the common name for a large species of African land snail native to the humid zones of Western Africa, south of the Sahara Desert. It has been introduced to many countries on other continents and has become a serious crop pest worldwide. The giant African snail reproduces rapidly, eats a wide variety of plants, and may spread diseases to both plants and people (Mead, 1961).

2.4 The anatomy of snails

The giant African snail has an elongated spiral-shaped shell that is usually off-white and mottled or striped with yellow. The shell grows to about 15 cm (about 6 in) in length, but can grow up to 23 cm (9 in) making it the world's largest land mollusk. The giant African snail lives for about five years with most of its growth occurring in the first year (Odaibo, 1997).

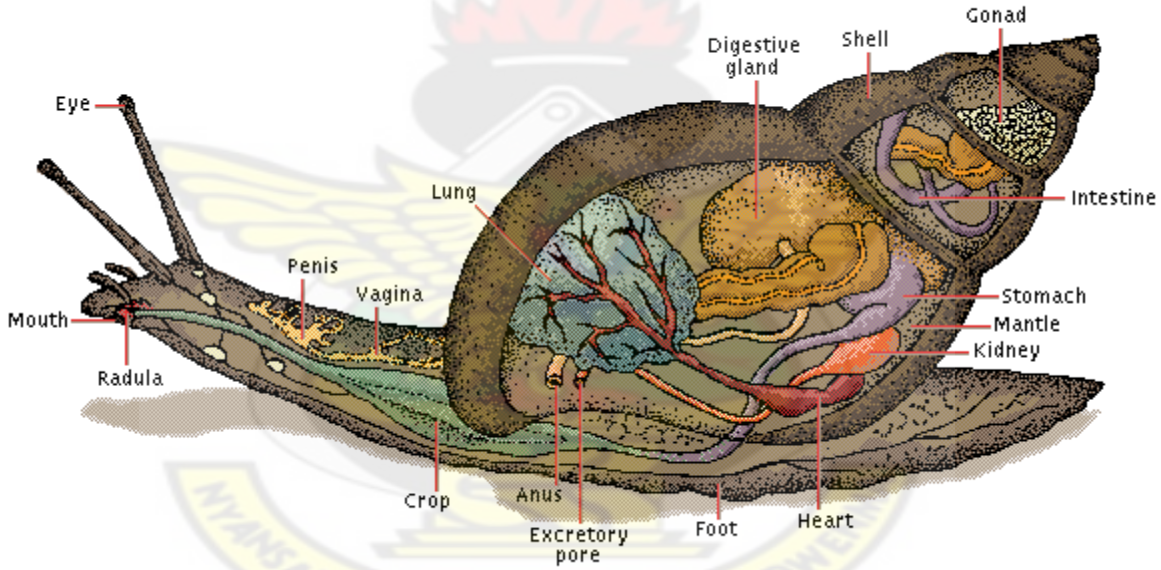


Figure 1: Anatomy of giant African snail (Microsoft Encarta, 2004 edition)

Giant African snails are hermaphrodites (each individual has both male and female sex organs), but mating of two individuals is necessary for fertilization of the eggs. One individual can produce up to 300 eggs. Eggs are laid in cool, moist soil or under objects and they hatch after 11 to 40 days. The young snail develops rapidly and requires a diet

high in lime (calcium oxide) and giant African snail infestations tend to occur in areas with soils high in lime (Odaibo, 1997).

The giant African snail has been introduced to the southern United States, Mexico, and Central America. Once established, the species has proven extremely difficult to eliminate without harming native, beneficial species. Many scientists feel that biological control (the use of natural predators, parasites, or disease-causing organisms) is the best approach to control these snails. Known predators of the giant African snail include firefly larvae, hermit crabs, coconut crabs, and carnivorous snails. Biological control methods are effective, although non-destructive native snails are often unintentional victim (Gernadi, 1951).

Giant African snails are not always considered pests. In some parts of Africa, these snails are used in traditional medicines and are relished as human food

2.5 Nutritional Value of Snail Meat

Snails are reared in commercial farms for their meat and shell. Snail meat is a delicacy in Asian cuisine, Japanese and Chinese in particular. The French delight escargot as an appetizer whereas in the Americas and Australia where it is commonly called abalone it is consumed as main meal. In African countries such as Nigeria, South Africa and Ghana, the land snail called Giant African Snail is also a traditional food. Snail recipes vary from cuisine to cuisine. Studies on the nutritional value of snail have reported that snail is high in protein but low in fat contents. Studies have shown that their meat is comparable in nutritional value to fish meal as a feed for poultry and swine (Elmslie, 1982). The protein

content is about 15 – 16 g / 100g meat which is about the same as most fish (Smith and Ojofeitimi, 1995).

It is estimated that snail meat is on fresh weight basis 15% protein, 2.4% fat and about 80% water (Saldanha *et al*, 2001). This makes snail healthy alternative food for people with high protein - low fat diet requirements. Land snail contain more crude protein and less fat than chicken (Elmslie, 1982) and are therefore a better source of protein for humans than chicken (and presumably ruminants) flesh. Land snail proteins contain all the essential amino acids required by humans. Snail meat is a rich source of protein and essential amino acids and therefore products from snail meat such as snail powder are recommended for both adults and children to provide protein which is required for growth and repair of worn out tissues. Snail meat is high in health benefiting essential fatty acids such as linoleic acids and linolenic acids. A study on a snail species in Brazil estimated that 75% of the fat in snail is unsaturated fatty acids. That is 57% polyunsaturated fatty acids, 15.5% of monounsaturated fatty acids, and 23.25% of saturated fatty acids. Land snail also contains the five essential unsaturated fatty acids but rather in small amounts and with much less in the ω-3 group considered so important to development of brain and vision function in utero and during the first two year of life than the ω -6 group (Su *et al*., 2004).

2.6 Snail meat and some acclaimed health benefits

Snail meat has traditionally been a major ingredient in the diet of most people living in the forest belt of West Africa and it has been consumed since prehistoric times (Beckett, 1964; Cobbinah, 1993). In addition to being rich in nutrient, snail meat has been shown to

have medicinal value and can treat ailments including whooping cough and other conditions (Table 1) (Akinnusi, 1998). Due to its high iron content it is considered important in the treatment and prevention of anaemia. In the past, it was recommended as a means of combating ulcers and asthma (Akinnusi, 1998). In traditional homes, snail meat is used to prepare light soup and 'kontomere' soup in Ghana and pepper soup in Nigeria.

Table 1: Medicinal uses of the African giant snail among rural people in Ghana

Part of snail used	Preparation	Conditions used for
Meat	Soup	Suppression of hypertension
		Curtails aggression
		Malformation of bone structure
		Nourishment of lactation mothers
		Promotion of easy child labour
		Cure anaemia
		Suppression of convulsion
		Stops bleeding from cuts
		Healing of amputated fingers
		Treatment of eye problems
Fluid	Soup	Circumcision of male children
		Suppression of small pox
		Anti- rheumatic

Source: Akinnusi (1998)

2.7 Microbial contamination associated with snail meat

Snails are gastropods and tend to walk on their belly. They may be found gliding on the surface of soils or buried under the soil or leaves. For this reason, the shell and meat of snails are exposed to a spectrum of microoganisms. Live bacteria may be present in lymph nodes and certain parts of the body, some of which may remain after evisceration (Girard, 1992). Live bacteria are also found in the gut of animals which play a useful role in digestion. Some of these microoganisms find their way to the carcass during dressing processes (Wilson, 1981). Other sources of microbial contamination include the hands, tools, utensils, clothing and others used in preparing the snail meat before drying. Microoganisms associated with snail meat include aerobic mesophils, halophilic bacteria, coliforms, faecal coli, *Clostridium* spp., *Staphylococcus aureus* and molds (Speck 1984; Harris *et.al* 1975).

These different kinds of microoganisms have different characteristics. Some may multiply rapidly at around 10 °C while others multiply rapidly at different temperatures. Some contain proteolytic enzymes which attack the protein portion of the meat causing putrefaction which results in the production of an unpleasant putrid odour. Others also cause fat oxidation to produce free fatty acids of unpleasant smell. Some have little or no effect on the meat while some microoganisms may release gummy substances producing slimes on the meat (Wilson, 1981).

2.8 Principles of Preservation of Shelf-Stable Dried Meat Products

In general, the term “shelf-stable product” refers to those products that do not require refrigeration or freezing for safety and acceptable organoleptic characteristics. Most

often, the products are stored at “room temperature” (ambient). This shelf-stability also is often dependent upon the proper packaging to control oxidation and potential mold growth. The shelf-life for these types of products is usually defined for acceptable quality, not safety because the safety has been addressed in the production process. The shelf-life of the product is defined as the time the specific product can be stored under specified conditions that retains organoleptic acceptability. Shelf-life is determined by two kinds of deterioration: microbiological (spoilage) and chemical (oxidation) (Wilson, 1981).

2.8.1 Shelf-stability and Hurdle Effect

Shelf-stability is due to a combination of factors, otherwise known as the “hurdle effect”. The interaction of these factors affects specific microorganisms and chemical reactions. Controlling the various factors and interactions maximizes the total effect and achieves shelf-stability. Food preservation technologies usually are classified into three types (Beauchat, 1981).

1. Prevention/removal of contamination e.g., decontamination of raw materials (steam treatment and organic acid washes of carcasses, irradiation of spices), aseptic processing
2. Inactivation of microorganisms e.g., heat (pasteurization, sterilization), high pressure processing
3. Slowing or complete inhibition of microbial growth e.g., low temp, water activity, redox potential, pH, or preservatives (Beauchat, 1981).

For dried meat products, preservation is mostly due to the slowing or complete inhibition of growth, although inactivation of pathogens such as *E. coli* O157:H7 is also involved (Adams and Moss, 1995). The most common factors relating to the safety/shelf-stability in dried meat products are water activity (a_w) , pH , time/temperature/relative humidity , salt/brine strength and microflora types (Adams and Moss, 1995).

With dried meat products, water activity probably is the most important factor contributing to shelf-stability over the total range of products (that is if pathogens are still viable, the product is adulterated) (Beauchat, 1981).

The product pH is the second most important factor, particularly considering that many of these dried meat products are fermented to some extent, or exhibit some microbial activity to yield the final product characteristics (Adams and Moss, 1995).

Inhibition of microorganisms by pH depends on many factors, including the type of acid and the temperature. The minimum pH for growth of *E. coli* O157:H7 is generally closer to 4.4, but it will survive well at lower pH values, especially if refrigerated (Adams and Moss, 1995). Microbiological minimum or maximum limits for growth are primarily due to temperature, water activity, pH and/or the presence of preservatives (Adams and Moss, 1995). The limits of water activity and pH as shown above apply only when all other factors are optimal for growth of the specific microorganism. In food materials, especially dried meats, the environmental conditions are hardly optimal and if more than one preservative effect (i.e., hurdle) is present, the effects may be added together (synergistic), and may even be more effective than the two factors alone. The hurdle

effect occurs when the combination of inhibitors is more restrictive than the individual inhibitors alone – a synergistic effect.

The most important hurdles in food preservation are.

• High temperature

• Low temperature

• reduced water activity

• increased acidity

• reduced redox potential

• Preservatives and competitive micro flora.

For shelf-stable dried meats, the last five hurdles are of primary importance, since these products are not sterilized, often not pasteurized, and certainly not distributed frozen (Wilson, 1981).

2.8.2 Formulation and Ingredients Important for Shelf-Stability

Salt (sodium chloride) is the most important ingredient used in the manufacture of dried meat products. Salt exhibits many functions including suppressing microbial growth, reducing water activity, releasing salt soluble proteins, penetrating easily into meats enhancing cure penetration, flavour and showing a pro-oxidant effect (Ihekoronye and Ngoddy, 1985). The percent salt in a meat product is not as important as the brine strength. The brine strength (sometimes referred to as water-phase salt) is the percent salt divided by the percent salt plus percent moisture in the same product. In dried meats that are manufactured with injected or immersed brine, the salometer reading expresses the strength or salt content in the brine (Ihekoronye and Ngoddy, 1985).

2.8.3 Packaging

The packaging system for dried meats is very important for chemical and microbial shelf-stability. Although most dried meats are shelf-stable with regard to food safety regardless of packaging (due to lower water activity, pH), the proper packaging prevents potential mold growth (that can increase the pH, and potentially allow growth of pathogens) and product oxidation that is undesirable organoleptically. Generally, the products are packaged under vacuum or modified atmosphere where the oxygen is eliminated. In MAP (modified atmosphere packaged) products, the total elimination of oxygen often is accomplished through the use of oxygen scavengers, which are added in the packaging process, either in packets or incorporated into the film. These scavengers remove any residual oxygen that may still be present after packaging.

2.8.4 Critical Processing Stages for Shelf-Stability and Safety

Most of the dried meat products rely on the interaction of several parameters to achieve stability and safety. Many steps are controlled, but only a few are truly critical. Generally the critical control points for fermented shelf-stable products are fermentation, heating and, sometimes, drying. For non-fermented salt-cured products, the salting step is critical, and for dried products the drying step is critical. For some products, such as freeze-dried products or bacon bits, a cooking step may also be critical. The main control points in the manufacture of most shelf-stable dried meats are primarily focused on the initial formulation stages where the ingredients are combined with the meat and subsequently processed.

2.9 The concept of meat drying

Drying refers to any process by which water is removed from a substance. It can also be said to be the removal of volatile substances by heat from a mixture that yields a solid product (Keey, 1975). The principal volatile substance is water, and water is the constituent whose removal is sought. Drying is usually the last unit operation before storage and dispatch.

The reasons for dying are quite diverse. Sometimes drying is carried out to reduce weight and thus reduce cost of transportation of product or to ease handling. Many food materials must be dried to bring their moisture content to a prescribed level to preserve them for storage and to enable shipment without the need for refrigeration (Perry, 1963).

The diversity of reasons is also matched by the diversity of methods of drying. Throughout history, man has used wind and sun to dry materials for his daily needs (Perry, 1963). While informal methods are still employed in areas where the climate is favourable, mere exposure to the elements is too slow and uncertain as a way of drying. Forced-drying methods were thus adopted from the earliest of times. The available wind was channelled by the careful stacking of the goods, and the sun's warmth was replaced by fire. Kilns for drying corn after harvesting were built in the damp fringes of Europe from the iron ages onwards (Parker, 1963). For many centuries, drying methods were still very crude. For example, concentrated milk is a powder produced by driving off the aqueous portion by gentle heat. Vegetables too, were preserved by oven drying under gentle heat. Simple stoves were being used to dry materials such as starch and lump salt. As the need arose in each industry for more reliable and quicker drying methods, so

equipment was developed to that effect. This led to the proliferation of many drying techniques (Perry, 1963).

2.9.1 Methods of drying

Drying methods can be grouped by the way in which heat is supplied to the moist material and by the mode of operation, whether continuous or batch (Keey, 1975). There are four main methods of heating and these are convective, conductive, radiative, and dielectric heating (Perry, 1963)..

Convective heating is employed by most thermal dryers. The drying conditions can readily be controlled by the temperature and humidity of the warm air that evaporates and conveys away the moisture. There is some insurance against overheating of the drying material since its temperature can never exceed that of the incoming air. However, convective dryers are sometimes thermally inefficient due to high heat losses in the outlet gases. Examples of a convective dryer are the smoke dryer and the gas oven dryers (Perry, 1963).

With conductive heating, heat for evaporating the moisture passes through the material from a hot surface. If the material to be dried is very thin or very wet, then conductive heating may be employed. The thermal economy is good but drying temperatures are higher than in convective heating. An example of a conductive dryer is the drum dryer. It is a slowly rotating heated drum or drums. As the drums revolve, moisture evaporates from the material, usually slurries, and finally the dried material is peeled off with a knife-edge (Perry, 1963).

Radiative heating is a method in which energy is supplied from electromagnetic radiation, with the wavelength ranging from those of solar radiation to those of microwaves (0.2 m-0.2 μm). Radiations within this range barely penetrate beyond the surface of the exposed material and the host material only accepts most of the incident energy for radiation of certain wavelengths. Since many materials absorb well in the 4 - 8 μm waveband, infra red radiation, heating is used in drying film, coatings, and sheet materials. Suitable radiators include low-temperature, liquid-heated metal panels and high-temperature quartz lamp (Perry, 1963). An example of this type of dryer is the solar dryer.

The last method of heating is dielectric heating. When a moist dielectric material is placed is an electric field oscillating very rapidly (10 MHz), energy is dissipated. Dielectric heating, unlike the other methods is internally generated throughout the whole materials. Since the dielectric constants of liquids are often much higher than those of solids, the heat developed rises rapidly with increasing moisture content. This property provides a convenient, self-adaptive means of attaining a uniform dry product. Since the energy generated by high frequency equipment is more costly than that available from other sources, dielectric drying is commercially viable only in rare instances (Perry, 1963).

2.9.2 Classification of dryers

Many dryers are currently being marketed and a simple classification of dryers into a few generic types is impossible. The form of the material being handled has been used in a way to classify dryers. Beside the nature of the material fed, Perry (1963) considers the manner in which the material progresses through the dryer in drawing up a guide to the

selection of dryers. The most thorough attempt to sort out dryers was presented by Keey (1975) who devised a decimal classification based on the following considerations:

- The temperature and pressure level in the dryer
- The method of heating the material to be dried
- The method of moving the moist material through the dryer
- The mechanical aid, if any, to improve drying
- The method of circulating the air and its influence, if any, on the measurement of the moist material
- The way in which the material is supported
- The nature of the wet material and the manner of its introduction into the dryer
- The heating medium

This comprehensive framework forms a useful aid in making an initial selection of feasible dryers for a particular job (Keey, 1975).

2.9.3 Selection of dryers

The selection of dryers usually falls into two steps (Perry, 1963):

- Listing those dryers that can handle the material to be dried
- Estimating the yearly cost (capital charges and operational cost) of each dryer and eliminating the most costly alternatives.

The number of dryers selected can be reduced by considering the following:

- The mode of operation, whether batch or continuous
- The mode of heating, whether by contact or directly by convection and radiation
- and specific restraints imposed by the nature of the material.

2.9.4 Batch or continuous dryers

In general, a continuously working dryer will be chosen as this mode of working will probably integrate more easily into the remainder of the process and the unit cost of drying will often be less than in batch operation (Keey, 1975). As the production becomes smaller, the influence of capital costs on the total running costs becomes dominant, and relative cheapness of batch plant becomes attractive. In general, production rates under 5000 kg/day are best handled in a batch dryer, and rates over 50000 kg/day are best handled in a continuous dryer (Barish, 1962). There are other considerations. A simple oven with shelves can probably be built in the user's workshop, whereas a continuous dryer will often demand the expertise of the plant manufacturer. A batch dryer is more versatile: it can handle, in the same unit, different materials with various drying characteristics. Furthermore, closed control over the humidity potential can be maintained during the course of drying. Thus, batch kilns are still widely preferred to continuous kilns because of the difficulty in maintaining the right humidity profiles in the latter.

2.9.5 Direct or indirect heating

Direct heating, if possible, is preferred for a number of reasons. The material is heated principally by convection from the surrounding air, the temperature of which can be closely controlled to ensure that the material is never warmed above a specified temperature. In general, directly heated dryers are cheaper than those indirectly heated due to the absence of jackets or tubes to hold the heating medium.

There are however a few drawbacks such as poor overall thermal efficiency, a probable reaction of the material with oxygen and other gases in contact with the material. Also circulating air may pick up fluffy and powdery materials with subsequent loss of material (Perry, 1963). These can be overcome by appropriate equipment design and careful operation. The paramount criteria in selecting a dryer are the capital, and operating costs of the proposed plant. Other considerations include safety, ease of operation and maintenance and long term commercial risks (Anon, 1969).

2.9.6 Cost of drying

The cost of drying is rarely an insignificant item, and occasionally is a factor that restraints the growth of a particular technology, as with freeze-drying. The costliness of the operation may be aggravated by the seasonal nature of some industries handling agricultural produce such as snails. Drying costs fall into two categories: those associated with the capital cost of the installation, and those with running it. It is also necessary to compare competitive dryers that, while meeting the technical specifications set, differ in their capital and operating costs (Anon, 1969).

2.9.7 Solar drying

Drying meat under natural temperatures, humidity and circulation of air, including direct influence of sun rays, is the oldest method of meat preservation (Wall *et al*., 2001). It consists of a gradual dehydration of pieces of meat cut to a specific uniform shape that permits the equal and simultaneous drying of whole batches of meat (Wall *et al*., 2001).

Warm, dry air of a low humidity of about 30% and relatively small temperature differences between day and night are optimal conditions for meat drying. However, meat drying can also be carried out with good results under less favourable circumstances when basic hygiene and technological rules are observed. Intensity and duration of drying process depend on air temperature, humidity and air circulation. Drying will be faster under high temperatures, low humidity and intensive air circulation (Wall *et al*., 2001). Reducing the moisture content of the meat is achieved by evaporation of water from the peripheral zone of the meat to the surrounding air and the continuous migration of water from the deeper meat layers to the peripheral zone. There is relatively high evaporation of water out of the meat during the first day of drying, after which it decreases continuously. After drying the meat for three or four days, weight losses of up to 60-70% can be observed, equivalent to the amount of moisture evaporated. Consequently, moisture losses can be monitored by controlling the weight of a batch during drying (Arason, 2003). Continuous evaporation and weight losses during drying cause changes in the shape of the meat through shrinkage of the muscle and connective tissues. The meat pieces become smaller, thinner and to some degree wrinkled. The consistency also changes from soft to firm to hard (Arason, 2003).

In addition to these physical changes, there are also certain specific biochemical reactions with a strong impact on the organoleptic characteristics of the product. Meat used for drying in developing countries is usually derived from unchilled carcasses, and rapid ripening processes occur during the first stage of drying as the meat temperature continue to remain relatively high . For this reason the specific flavour of dried meat is completely different from the characteristic flavour of fresh meat (Wilson, 1981).

Undesirable alterations may occur in dried meat when there is a high percentage of fatty tissue in the raw meat. The rather high temperatures during meat drying and storage cause intensive oxidation (rancidity) of the fat and an unpleasant rancid flavour which strongly influences the palatability of the product. Snail meat is low in fat (Fagbuaro *et al*., 2006) and therefore undesirable changes due to fat oxidation may be insignificant.

2.9.8 Smoke drying

Smoking of meat is a technique in which meat is exposed directly to wood smoke which may be generated by a variety of methods. There are various substances in the smoke produced from wood which contribute to the flavour and the appearance of the smoked meat product and which has a certain preserving effect on the product (Asita and Campbell, 1990). The preserving effect of common smoking is not very significant when storing the product without a cold chain (Draudt, 1963). On the other hand, intensive or prolonged smoking may considerably increase the shelf-life of the product, but it also has an unfavourable effect on flavour. Whereas a light smoke aroma generally enhances the orgnaloptic properties of the product, intensive smoking has a negative effect on the quality, especially in the case of prolonged storage in which concentrated smoke compounds develop increasingly unpleasant tarry flavours (Asita and Campbell, 1990).

In view of the above, smoking in order to preserve meat can only be considered as an emergency measure when no other preservation methods can be carried out. This may be the case during wet weather or generally under a humid climate, or when the preservation has to be completed as fast as possible because of the need of immediate transport for instance after game-hunting (Draudt, 1963).

Intensive meat smoking (hot-smoking) is carried out at a temperature of at least 70 °C and is always a combination of two effects, drying the meat by reducing its moisture content through hot air and the condensation of smoke particles on the meat surface together with their penetration into the inner layers of the product (Draudt, 1963). Both have preservative effects and prolong the half-life of the product. The smoke particles include methanal, ethanal, dimethyl propanone, methanol, ethanol, phenols, methanoic and ethanoic acids, resins, waxes, tars, and many other materials (Ihekoronye and Ngoddy, 1985). These are all present in minute amounts. Deposition of phenolic compounds also has antioxidant effect on the dry product and prolongs the shelf-life by preventing rancidity of fats from taking place (Girard, 1992).

To smoke the meat, large strips and /or pieces, with and without bones, are dried by smoking in special drying/smoking places. The smoke is produced in these cases by glowing wood. Often, meat is prepared quickly by drying and smoking over a fire. In this case, the meat is not only smoked, but half-cooked or roasted. Normally, meat from this treatment is not well prepared and has to be consumed soon after drying, otherwise is will spoil quickly (Girard, 1992).

The quality of traditionally smoke -dried meat is generally poor based on microbiological analysis. This is not only owing to poor meat quality or inadequate smoking devices, but mainly because smoke-drying is a rather rough treatment for the meat. The process is fast and has a certain preserving effect, but at the cost of quality (Tettey *et al*., 1997).

Quality losses are even more obvious when failures in preparing the raw material occur. When, for example, the thickness of the meat parts to be smoked ranges from about 3 cm

to 15 cm, uniform drying will not be achieved. The smaller pieces will be over-dried and the thicker ones may still remain with high moisture content in the product centre. The results of faulty drying and smoking are a too strong smoke flavour, lack of rehydration capacity of the smaller parts and fast spoilage of the thicker parts (Girard, 1992). For effective smoke-drying, the meat thickness should not exceed 7 cm to achieve products which are stable for a certain period without refrigeration. Apart from primitive smoking places with just a fire below the meat, the construction of special smoking kilns has been suggested for smoke – drying of meat (Draudt, 1963).

The effect of light smoking could be of interest for the production of dried meat. It is carried out at smoking temperatures not higher than 28 °C and is not suitable for meat preservation without a cold chain, but it adds a smoke flavour to the product and inhibits the growth of molds and yeast on the product's surface owing to the fungistatic smoke compounds (Draudt, 1963). Thus, light smoking may be used for the prevention of growth of molds during the storage period of dried meat, especially under humid climatic conditions. In both light and intensive smoking, however, the smoke should be generated from cured hardwood in order to avoid too much smoke particles and gums deposited on the meat when using softwood (Daun, 1979).

2.9.9 Effect of smoke on nutritive value of meat

The phenols and polyphenols react with the sulfhydryl groups of the proteins and the carbonyl groups react with the amino groups. These reactions are likely to cause losses of amino acids like lysine (Ellis, 2001).

2.9.9.1 Smoke generation

Smoke is generated using wood or saw dust. The temperature has a bearing on the contents of smoke. As the temperatures increase over 300 °C the ratio of acids to phenols is reduced since acids are produced at lower temperature and phenols at higher temperatures. The best quality smoke is produced at a temperature of 343 - 400 °C with subsequent oxidation temperature of 248 °C. Temperatures around 400 °C encourage the production of the polycyclic hydrocarbons. To reduce the production of these a more practical temperature for smoke production might be closer to the 343 °C temperature (Ellis, 2001).

2.9.9.2 Humidity during smoking

The humidity during smoking in the smokehouse is important as it affects the smoke deposition on the product as stated:

- High humidity favours smoke deposition but also tend to limit colour development.
- With high humidity there is higher amount of smoke penetration.
- When humidity is too low the smoke is deposited on the surface only and desirable colour is not achieved. It is likely to acquire a dull brown tan.
- High humidity does not necessarily reduce shrinkage of the products rather it may encourage fat rendering.
- In case of animal or collagen casings somewhat higher humidity gives good results.

- With collagen casings smoking with low humidity hardens the surface and produce a low quality product.
- Whereas too high humidity softens the surface therefore a balanced humidity application has to be made (Ellis, 2001).

Air circulation in a smokehouse

Air circulation is critical as it promotes uniform heating of the product. High air velocities tend to produce more rapid drying along with rapid heating and it is also difficult to maintain high air velocities unless the dampers are kept tightly closed to prevent the loss of smoke (Ellis, 2001).

CHAPTER THREE

MATERIALS AND METHODS

3.0 Source of snails

The African giant snails shown in Figure 2 were obtained from a snail farm in Amanfrom prisons camp in Kumasi, Ashanti Region of Ghana. The main feed for the snails were pawpaw leaves and the ages of the snails used for this studies varied from ten to twenty months.

Figure 2: The giant African snails

3.1 The purging process

After collection the snails were put in a wooden box filled with sawdust (Figure 3) for five days to ensure that no food was left in the intestinal tract. During this period of purging, the snails were not given food. The purging process was aimed at reducing the microbial load inside the intestinal tract of the snails and also to get rid of any contaminating material that may be harmful to humans when eaten. The intestinal tract of

snail contains a lot of substances and microorganisms that can contaminate the meat during evisceration. At the end of five days of purging a whitish and almost clear and slimy fluid that can affect drying of the snail meat, was produced by the snails which marked the end of purging.

Figure 3: Snails being purged in a wooden box containing sawdust.

3.2 Heating and evisceration

After the purging process the snails were washed in clean water with a little salt (5% w/v NaCl). After 30 seconds the water turned white and clear which was an indication that the snails were being cleaned. The water was changed 10 times until it was clear. The snails were then heated in 5% w/v NaCl solution for about twenty minutes at a maximum temperature of 60 °C to aid evisceration and also reduce the microbial load. The preheating process also breaks up the chemical bonds in the proteins and other macromolecules in the meat thereby softening the meat and releasing water from the meat which might affect drying. After heating, the snails were allowed to cool to room temperature and the viscera removed from the shell using a clean knife. The edible portion was separated from the intestinal tract. The snail meats were cut into smaller

pieces of about 5 cm x 4 cm dimension in sizes. This increases the surface area of the meat and facilitates drying.

3.3 Drying

The prepared samples were subjected to three different methods of drying, namely solar drying, smoke drying and gas-oven drying each to a moisture content of about 2.5 %. After drying, the meats were milled into fine powder using a blender and the powder packaged into transparent sterile polyethylene bags (1.5µm thick) for further analysis.

3.3.1 Solar drying

Solar drying of the snail meats was carried out using a solar dryer shown in Figure 4.

The solar dryer was constructed from wood, glass and transparent asbestos roofing sheet. Each solar dryer is of the following dimensions: 181cm long, 140 cm wide and 117 cm high at the front and 86 cm high at the back. Each solar dryer has 8 shelves, 4 in front and 4 at the back. Each shelf has a dimension of 83 cm long, 65 cm wide and 14 cm deep and it is laced with galvanised wire nets on which the samples are placed.

Figure 4: Solar dryer

The solar dryer employs solar radiation in drying materials. Each dryer has a dark absorbing surface with transparent asbestos roof and eight glass windows. The transparent asbestos roof and the transparent glass windows allow the sun's rays to pass through and to be incident on the dark surface inside the dryer. The dark surface absorbs the sun's rays causing it to heat up. After heating up, it emits its heat into the enclosed tent. This raises the temperature within the cabinet but because it is enclosed, the heat is not readily dissipated (Lawand, 1966). An average temperature of 57 °C and relative humidity of 40 – 45 % were used for drying. Temperature and relative humidity readings were taken using a thermo-hygrometer. It took six days for the meat to be well dried (attained an average moisture content of 2.85 %).

3.3.2 Gas- oven drying

The gas dryer shown in Figure 5 is a wooden structure raised on a 25 cm high stand.

Figure 5: Gas- oven dryer

The inside dimensions of the drying chamber are 76 cm long, 60 cm wide and 122 cm high. The dimensions of the walls of the fire box are 100 cm long, 96 cm wide and 59 cm high. The gas dryer is fitted with 11 pairs of parallel supports on which the trays carrying the sample slide. The sample is placed on a series of galvanised wire trays. The front of the drying unit is closed by a single door, hinged onto the framework. Drying was carried out at a temperature and relative humidity range of 80 °C and 40 – 45% respectively for 8 hours to reach a final average moisture content of 2.59 %.

3.3.3 Smoke drying

A smoke dryer shown in Figure 6 was used for drying.

Figure 6: Smoke dryer

The smoke dryer consists of a wooden smoke unit placed above a fire box. The fire box is built from sun dried clay blocks. The outside dimensions of the fire box are 107 cm long, 104 cm wide and 118 cm high. The inside dimensions of the walls of the fire box are 100 cm long, 96 cm wide and 59 cm high. The front wall has a 32 X 32 cm stoke hole near the bottom for inserting the wood and controlling the fire and smoke. The wooden smoke unit is fitted with 8 pairs of parallel supports on which the trays carrying the sample slide. The sample is placed on a series of galvanised wire trays. The front of the smoke unit is closed by two wooden doors, hinged onto the framework. There is a pair of cabinets between the doors and the fire box which can be opened to allow a relatively small quantity of air and smoke to pass to control temperature and relative humidity inside the drying chamber. Charcoal from hard wood and sawdust were used to generate heat and the smoke. The quantity of charcoal and sawdust were controlled to obtain an average temperature of 71 °C inside the drying chamber which was used for drying. It took 10 hours for the samples to dry to an average moisture content of 2.78%.

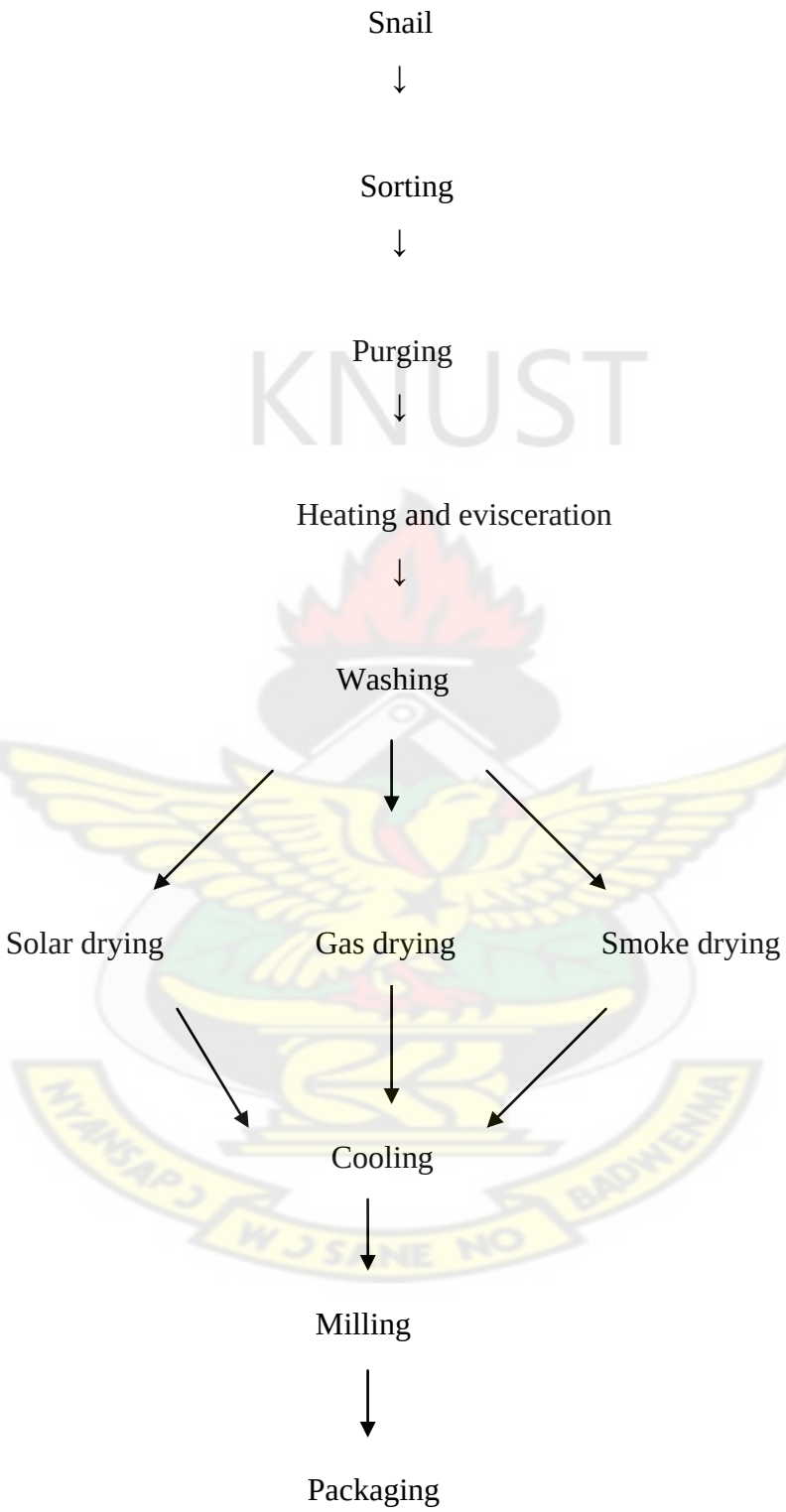


Figure 7: Flow diagram of snail meat powder processing

3.4 Proximate analyses on snail meat

Proximate analyses were carried out on the fresh snail meat as well as on the dry snail meat obtained from the three dryers.

3.4.1 Moisture content determination

Two (2.0) grams of sample was accurately weighed into a previously dried and weighed glass crucible. The sample was then dried in a thermostatically controlled forced air oven (Galena, England) at 105 °C for 8 hours to a constant weight. The glass crucibles were removed and transferred into desiccators for cooling after which they were weighed. Moisture content was determined as shown in Appendix I, (AOAC, 1990).

3.4.2 Crude fat determination

Two (2.0) grams of each dried snail powder sample was transferred into a paper thimble plugged at the opening with glass wool and placed into thimble holder. Petroleum ether of volume 150 ml was measured into a previously dried and weighed 250 ml round-bottom flask and this was assembled together with the thimble holder and its contents.

The Quickfit condenser was connected to the Soxhlet Extractor and refluxed for sixteen (16) hours on low heat on a heating mantle. After extraction the flask containing the fat was dried at 105°C in an oven for 30 minutes, cooled in a desiccator and the weight of the fat collected was determined and expressed as percentage crude fat (Appendix I), (AOAC, 1990)

3.4.3 Crude protein determination

The kjeldahl method (AOAC, 1990) was used for the determination of crude protein content of the snail meat samples.

Digestion: Two (2.0) grams of sample was weighed and placed in a kjeldahl digestion flask together with a small amount of selenium-based catalyst and a few anti-bumping granules. Concentrated $H_2 SO_4$ of volume 25 ml was added and the tube shaken until the entire sample was thoroughly wet. The flask was placed on a digestion burner in a fumed chamber and heated (approximately 410 °C) for 2 hours until the resulting solution was clear. This was then cooled to room temperature and the digested sample solution transferred into a 100 ml volumetric flask and made up to the mark.

Distillation: The distillation apparatus was flushed with distilled water for about 10 minutes. Twenty five (25) ml of 2 % boric acid was poured into a 250 ml conical flask and 3 drops of mixed indicator added, turning the solution pink. The conical flask and its contents were placed under the condenser with the tip of the condenser completely immersed in the boric acid solution. Ten millilitres (10 ml) of the digested sample solution and about 20 ml of 40 $^{o}/_{o}$ NaOH solution were transferred into the decomposition flask and the funnel stopcock well closed. Ammonia (NH_3) liberated during the distillation was collected by the boric acid solution, changing it from pink to bluish-green. The distillate was titrated against 0.1 N hydrochloric acid (HCI) solution until the solution changed from bluish-green to pink. The end point was recorded and the titre values obtained were used to calculate the total nitrogen and the percentage crude protein determined (Appendix I), (AOAC, 1990).

3.4.4 Ash determination

Two grams (2.0 g) of each of the three snail powder samples in duplicates was weighed into a pre-ignited and previously weighed porcelain crucible. The samples were placed in a muffle furnace (Gallenkamp, England) and ignited for 2 hours at 600° C. After ashing, the crucibles were cooled to about 105 °C in a forced air oven before cooling them further to room temperature in a desiccator. The crucibles and their contents were weighed, and the weight reported as percentage ash content (Appendix I), (AOAC, 1990).

3.4.5 Total carbohydrate determination

Total carbohydrate was calculated as shown in Appendix I.

Results of the proximate analysis are shown in Table 2.

3.4.6 Energy content determination

The energy value was determined based on the Atwater factor and was obtained by multiplying the values for percentage composition of carbohydrate, fat, and protein expressed as calories per gram or kilojoules per gram. The calorific values of various food components as well as the formula for calculating the energy value of foods are shown in Appendix I.

3.5 Microbiological analysis

Microbiological analysis was conducted on the following samples to enumerate bacteria and mold:

- Fresh snail samples (before purging)

- Snail samples after purging
- Preheated snail samples
- Snail samples from the three drying processes just after processing
- Dried processed samples after six (6) weeks of storage
- Dried processed samples after fifteen (15) weeks of storage, and
- Dried processed samples after thirty weeks (30) weeks of storage
- Dried snail meat samples bought from the open market

3.5.1 Sample preparation for microbiological analysis

The fresh and preheated samples were initially chopped into small pieces using a knife before milling into a paste using a previously washed and cleaned blender. The dried snail samples from the three drying processes were milled whole in a previously washed and dried blender.

One gram (1g) of each milled sample was weighed into a separate test tube containing 10 ml of sterile $0.1^{o}/_{o}$ peptone solution. The mixture was then shaken for 2-3 mins, and allowed to settle for about 2 mins. Appropriate dilutions (from 10^{-1} to10^{-12}) of the snail suspension (extract) were then prepared.

3.5.2 Microbiological analysis for bacteria

One ml of the diluents was inoculated onto sterile plate count agar (PCA) using the surface plating technique. Plates were then incubated at 37^{o}C for 48 hrs in a Gallenkamp incubator. Colonies formed were counted using the Gallenkamp colony

counter and expressed as colony forming units per gram (cfu/g) of snail meat. Results are shown in Table 3.

3.5.3 Microbiological analysis for mold

One ml of the diluents was inoculated onto sterile Potato Dextrose Agar (PDA) (BDH) using surface plating technique. Plates were then inoculated at 25^{o}C in a Gallenkamp incubator for 48 hours. Colonies formed were counted using a Gallenkamp colony counter. Counts were expressed as Colony Forming Units per gram (cfu/g) of snail meat. Table 4 shows the results obtained for the mold count.

3.6 Sensory evaluation on dry snail powder

Powdered samples obtained from the three drying processes were subjected to sensory evaluation. Twenty (20) panellists, who regularly eat snail meat, were selected and trained for the sensory evaluation tests. Attributes determined for the degree of preference (using a ranking test) were appearance (colour) and aroma. The score card used in analyzing the various attributes of the snail samples are shown in Appendix II.

3.7 ‘shito’ preparations

The snail powdered sample with the highest sensory qualities (smoke dried sample) was used as a substitute for shrimp powder in ‘shito’ preparation. The ingredients for the preparation are as follows:

- Smoke dried snail powder (8 table spoons)
- Powdered pepper (3 table spoons)

- Tomato paste (10 table spoons)
- Grounded onion, ginger and garlic (5 table spoons)
- Vegetable oil (1 litre)
- Salt(1 table spoon)

Preparation:

The oil was put on fire for about 1 minute and the grounded onion, garlic and ginger added and stirred for about 3 minutes for the moisture in the stew to get dried. The tomato paste was then added and stirred for about 20 minutes to get browned. The powdered pepper was added followed by the salt to taste. Lastly, the powdered snail meat was added and stirred for about 5 minutes.

Shrimp powdered 'shito' was also prepared using the same method and ingredients but instead of snail powder, shrimp powder bought from the open market was used.

3.8 Sensory evaluation on 'shito'

The 'shito' samples were randomly presented to twenty (20) panellists, who regularly eat snail and shrimp. Attributes determined for the degree of preference (using the nine-point hedonic scale) were taste and aroma. Results of the test are shown in Table 8. The score card used in analyzing the various attributes of the 'shito' samples is shown in Appendix II.

3.7 Statistical Analysis

The data obtained from the proximate and microbiological analyses were subjected to statistical analysis using analysis of variance (ANOVA, completely randomised design procedure). This was to know whether significant variations ($p > 0.05$) existed among the means of values obtained from the proximate and microbiological analyses of snail samples from the three drying methods. The statistical package used was Costat Software Version 6.204. Multiple mean comparisons test using least significant difference (LSD) was computed to ascertain where the differences exist. The Kruskal Wallis test was used to ascertain whether there were significant differences ($p > 0.05$) in the various sensory attributes (appearance and aroma) of the three snail powdered samples as well as the 'shito' samples using the responses of the panellists.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Proximate analyses

Values of crude protein, moisture, ash and crude fat as shown in Table 2 varied according to the drying method.

Table 2: Some proximate values on the dry snail meat samples using the three drying procedures (dry weight basis).

	Parameters determined					
Snail meat sample	Protein	Fat	Ash	Moisture	Total CHO	Energy (KJ/100 g)
Smoke dried	88.02[a]	2.83[b]	3.20[a]	2.78[a]	3.17[b]	1654.94[b]
Gas dried	87.90[a]	1.68[c]	2.98[a]	2.59[a]	4.85[a]	1638.91[c]
Solar dried	87.52[a]	3.79[a]	3.00[a]	2.85[a]	2.84[c]	1676.35[a]
LSD (0.05)	**0.34**	**1.45**	**0.48**	**0.43**	**1.36**	**14.30**

Mean values with different superscript (a, b, c) in column are statistically different at $p > 0.05$
CHO = carbohydrate
The values are average of two determinations.

4.1.1 Moisture content

The final moisture content attained by the three dried samples was dependent on the processing conditions employed in the drying of the snail meat. For the smoke dried samples, a moisture content of 2.78 % was obtained after 10 hours of drying with an average drying temperature of 71 °C. The moisture value of the gas dried sample (2.59 %) was obtained after 8 hours of drying with an average temperature of 80 °C. In the

case of the solar drying, ambient temperature and time of drying were important factors. In this work, solar drying was carried out in November when the weather was quite dry and sunny and the humidity very low. An average temperature of 59 °C was attained in the solar dryer and a moisture content of 2.85 % was obtained for the samples after 6 days of drying. There was no significant difference ($p > 0.05$) in the values of moisture content of the dried snail meats. Moisture content of products can affect the shelf life and sensory qualities. The higher the moisture content the higher the microbial activity and growth and hence shorter shelf life. The moisture content of all the samples was kept very low and thus the powdered snail samples could be kept for a longer period of time and still maintain high sensory qualities. The results show that all the three dryers were very efficient in drying the samples.

4.1.2 Crude protein

From Table 2, the protein content of all the samples were relatively high compared to other proximate parameters of the samples. The high protein values were expected because snail meat is mostly muscles and most of the moisture was removed. The smoke-dried sample had the highest protein content of 88.02 % followed by the gas-dried sample with 87.90 % and the solar dried sample having the lowest value of 87.52 %. However these values are not significantly different ($p > 0.05$). Generally, most processes such as dehydration, canning and domestic cooking have little effect on the protein content and quality and even when denaturation occurs, it is of little practical importance on the protein content (Bender, 1978). The marginal differences in the values of protein content

of the samples could be attributed to experimental errors which might have occurred during reading of the instruments for the determination as well as slight differences in the moisture content of the dried products. Crude protein values obtained were relatively high compared to values reported by Watson (1971) which was between 68 – 71% on dry weight basis. This may be due to the differences in the moisture content of the samples, the purging and the source of the snail samples used as well as experimental errors.

4.1.3 Crude fat

Table 2 shows the values for crude fat obtained for the three samples. There were significant differences ($p < 0.05$) in the mean values obtained for all the samples. The solar dried samples had the highest fat content of 3.79 % followed by the smoke dried sample with 2.83 % and the gas dried samples having the lowest fat content of 1.68 %. The relatively low fat content of the gas dried and the smoke dried samples compared to the solar dried samples could be due to some level of fat melting which took place as a result of higher temperatures used for drying in gas and smoked dryers compared to the solar drier. Higher temperatures of 80 °C and 71 °C were recorded for drying in the gas and smoke dryers respectively, which might have resulted in an appreciable level of fat melting in the gas and smoke samples. A lower temperature of 57 °C was used for the solar drying and therefore resulted in the samples having higher fat content.

Oduro *et al.,* (2002) reported that there is an inverse relationship between the weight and fat content of snail meat. They observed that in *Achatina achatina* as the weight increased fat content decreased. The values obtained fell below the range of fat content (4.11 % -

5.06 % on dry weight basis) reported by Oduro *et al*., (2002). The recorded fat content could be explained by the difference in the sizes of the snails used for this work and the purging period when the animal used some of the fat for energy. With the rising incidence of hypertension and other cardiovascular diseases resulting from excessive eating of fatty foods and inadequate exercise (Burton *et al*., 1988), the eating of snail meat may help in preventing these problems.

4.1.4 Ash

The percentage of ash in a food sample gives an indication of the number and quantities of elements present. Beyond a certain threshold, however, the ash content may be an indication of possible contamination. Snails eat from varied food sources including the soil which may account for the relatively high values obtained from the ash determination. There was no significant difference ($p > 0.05$) in the mean values obtained from the three different drying methods (Table 2). The observed marginal differences could be due to differences in the moisture content of the samples and not the sizes of the snail meat used for this study since the size of snail has no effect on the ash content of the samples as reported by Oduro *et al*., (2002). Values obtained for ash content compare favourably with values reported by Gernadi (1951) (3.32%) and Mead (1961) (3.28%) on dry weight basis.

4.1.5 Total carbohydrate

Animals have low capacity for storing glycogen. Excess carbohydrate is metabolised into fat (Lehninger, 1987) and so the total carbohydrate in animal flesh is low. Typical values of total carbohydrate for some animals (fresh weight basis) as reported by Burton *et al.* (1988) were as follows: beef – 0.9 mg/g, crabs – 1.3 mg/g, clams – 3.4 mg/g, and oysters – 5.6 mg/g. Table 2 shows that the total carbohydrate values of the samples were 3.17 %, 4.85 % and 2.84 % for the smoke dried, gas dried and solar dried samples respectively. All the values are on dry weight basis. There were significant differences ($p > 0.05$) among the values. The values were affected by the percentage of other constituents (% protein, % fat, % ash, % moisture) of the sample under study. Thus, differences existed in the values reported by various workers on snails. Oduro *et al*., (2002) reported values ranging between 6.87 % and 7.89 % for snail meat. Generally, the values obtained were relatively low. This was expected because snail meat is basically animal protein and with the slow nature of its locomotion, it only needs to store small amount of glycogen for this purpose.

4.1.6 Energy content

There was significant difference ($p > 0.05$) in the energy content values of all the three samples. The solar dried samples had the highest value of 1676.35 kJ/100 g and the gas dried sample with the least value of 1638.91 kJ/100 g sample.

The differences in energy values of food depend on the amount of carbohydrate, protein and especially fat contained in that food. The energy content of the samples was quite high and thus snail meat can provide an appreciable amount of calories in the diet.

4.2 Microbiological analyses

Tables 3 and 4 show the results of the microbial analyses. The average number of bacteria was 2.67 x 10^{10} cfu/g whilst that of mold was 4.42 x 10^{11} cfu/g for the fresh snail meat before purging.

Table 3: Bacteria load (cfu/g) of samples before and after processing

Sample	Before purging	After purging	After preheating	Just after production	6 weeks of storage	15 weeks of storage	30 weeks of storage
Solar- dried	$2.67x10^{10}$	$4.53x10^{5}$	$3.35x10^{3}$	$2.12x10^{3}$	$4.32x10^{3}$	$6.34x10^{5}$	$3.19x10^{7}$
Gas- dried	$2.67x10^{10}$	$4.53x10^{5}$	$3.35x10^{3}$	$2.89x10^{2}$	$3.45x10^{3}$	$4.56x10^{4}$	$7.23x10^{6}$
Smoke- dried	$2.67x10^{10}$	$4.53x10^{5}$	$3.35x10^{3}$	$1.65x10^{1}$	$2.89x10^{1}$	$4.23x10^{3}$	$5.15x10^{4}$

Table 4: Mold load (cfu/g) of samples before and after processing

Sample	Before purging	After purging	After preheating	Just after production	6 weeks of storage	15 weeks of storage	30 weeks of storage
Solar- dried	4.42x 10^{11}	$6.53x10^{6}$	$4.23x10^{3}$	$3.53x10^{3}$	$6.32x10^{4}$	$7.32x10^{5}$	$4.19x10^{8}$
Gas- dried	4.42x 10^{11}	$6.53x10^{6}$	$4.23x10^{3}$	$3.18x10^{2}$	$4.35x10^{3}$	$2.56x10^{5}$	$8.11x10^{6}$
Smoke- dried	4.42x 10^{11}	$6.53x10^{6}$	$4.23x10^{3}$	$2.54x10^{1}$	$1.85x10^{2}$	$5.27x10^{3}$	$6.64x10^{4}$

The purging process had a significant effect on the microorganisms. It was very effective in reducing the initial microbial load of $2.67x10^{10}$ cfu/g in the fresh state to $4.53x10^{5}$ cfu/g for bacteria (Table 3) and from 4.42x 10^{11} cfu/g to $6.53x10^{6}$ cfu/g for molds (Table 4). Purging is important because it reduces the microbial load of the snails apart from emptying the intestinal tract of any food material which might be harmful to humans

when eaten. Other organisms like crabs are also purged before eaten for the same effect of reducing microbial load and removing any contaminating food material from the intestinal tract.

The preheating process also reduced the microbial load further from $4.53x10^5$ cfu/g to $3.35x10^3$ cfu/g for bacteria and from $6.53x10^6$ cfu/g to $4.23x10^3$ cfu/g for molds. The preheating process was done for about twenty minutes at a maximum temperature of 60 °C. This temperature and time combination was effective at killing most of the microoganisms.

Statistical analyses (Tables 5 and 6) show that there were significant differences ($p > 0.05$) in the microbial load of the samples just after processing throughout the thirty weeks of storage.

Table 5: Bacteria load (natural log) of samples at different periods after processing

Sample	Number of weeks after processing			
	0	6	15	30
Solar – dried	7.7 [a]	8.4[a]	13.4 [a]	17.3 [a]
Gas – dried	5.7 [b]	8.2 [b]	10.7 [b]	15.79 [b]
Smoke – dried	2.8 [c]	3.4 [c]	8.4[c]	10.9[c]
LSD (0.05)	**0.57**	**0.52**	**0.55**	**0.58**

Mean values with different superscript (a, b, c) in column are statistically different at $p > 0.05$

The initial numbers of microbes in the solar-dried sample were high compared to the other samples (Tables 3 and 4) and this was reflected in the number of microoganisms present in the samples after the thirty- week storage period. Compared to the other dryers,

the solar dryer was quite slow in drying the samples. Drying was carried out in November (dry season) when there was so much sunshine necessary for effective drying. An average temperature of 59 °C was attained in the solar dryer and an average moisture content of 2.85 % was attained after 6 days of drying. The relatively long period of time and low temperature for drying enabled more microoganisms to survive which led to the high initial number of bacteria and mold recorded. Nevertheless, there was a reduction in the microbial load (both bacteria and mold) after solar drying. The ultra- violet radiations in sunlight have a lethal effect on microoganisms (Lawand, 1966) and thereby reducing the microbial load from 3.35 x 10^3 cfu/g to 2.12 x 10^3 cfu/g for bacteria and from 4.23 x 10^3 cfu/g to 3.53 x 10^3 cfu/g for mold (Tables 3 and 4).

Table 6: Mold load (natural log) of samples at different periods after processing

Sample	Number of weeks after processing			
	0	6	15	30
Solar – dried	8.2 [a]	11.1[a]	13.5 [a]	19.9 [a]
Gas – dried	5.8 [b]	8.4 [b]	12.5 [b]	15.9 [b]
Smoke – dried	3.2 [c]	5.2 [c]	8.6 [c]	11.1[c]
LSD (0.05)	**0.52**	**0.56**	**0.51**	**0.57**

Mean values with different superscript (a, b, c) in column are statistically different at $p < 0.05$

The smoke dried samples had the least microbial load for both bacteria and mold (Tables 3 and 4) and there were significant differences ($p > 0.05$) (Tables 5 and 6) in the microbial load just after production through to the thirty week storage period.

The composition of smoke includes aldehydes, alcohols, organic acids, furfuraldehydes and phenols (Ihekoronye and Ngoddy, 1985). Some of these substances are bactericidal and others are bacteriostatic. These substances got deposited on the surface of the snail meat during the smoke drying process. The combined effect of these substances and heat in the smoke dryer (about 71 °C for 10 hours) killed most of the microorganisms and reduced their number from 3.35×10^3 cfu/g to 1.65×10^1 cfu/g for bacteria and from 4.23×10^3 cfu/g to 2.54×10^1 cfu/g for mold (Tables 3 and 4). Thus, apart from imparting flavour to food smoke also has a preservative effect on the food sample. The smoke dried sample was relatively stable in terms of microbial growth throughout the storage period. It had the least microbial load at the end of the thirty -week storage period with 5.15×10^4 cfu/g and 6.64×10^4 cfu/g for bacteria and molds respectively (Tables 3 and 4).

The gas -dried samples had relatively higher microbial load compared to the smoke dried samples both just after production and at the end of the thirty week storage period. The heat in the gas dryer killed and reduced the number of microoganisms from 3.35×10^3 cfu/g to 2.89×10^2 cfu/g for bacteria and from 4.23×10^3 cfu/g to 3.18×10^2 cfu/g for molds just after production (Tables 3 and 4). The drying conditions of temperature and duration of time (80 °C for 8 hours) were closer to the smoke drying (71°C for 10 hours) however the gas dried samples had relatively higher microbial load compared to the smoke dried samples. This could be explained by the fact that in the case of gas drying only heat was used to kill microoganisms whereas in the case of the smoke- drying both heat and smoke was employed. smoke particles contains compounds such as methanal, ethanal, dimethyl propanone, methanol, ethanol, phenols, methanoic and ethanoic acids,

resins, waxes, tars, and many other materials which kill microorganisms (Ihekoronye and Ngoddy, 1985).

A general trend of higher number of molds than bacteria was observed at every microbial count. This general trend could be explained by the fact that molds are generally more resistant to conditions such as reduced water activity and thus can survive at lower water activity than bacteria. The limiting water activity for molds lies between 0.88 and 0.95 and even some molds such as *Xeromyces bisporus* can survive and develop at a water activity as low as 0.6 (Girard, 1992). Unlike molds, the optimum water activity for the growth of bacteria is between 0.99 and 0.95 and below a value of 0.91, bacteria growth is generally inhibited (Girard, 1992).

There was also a general trend of increase in the microbial load after six, fifteen and thirty weeks of storage. This observation may be due to absorption of moisture by the samples which consequently increased water activity of the samples. The samples were stored in plastic bags which were not hermetically sealed and for that matter there was a possibility of air entrance which might contain moisture. With increasing water activity more microoganisms can survive and multiply leading to increased microbial loads over the storage period.

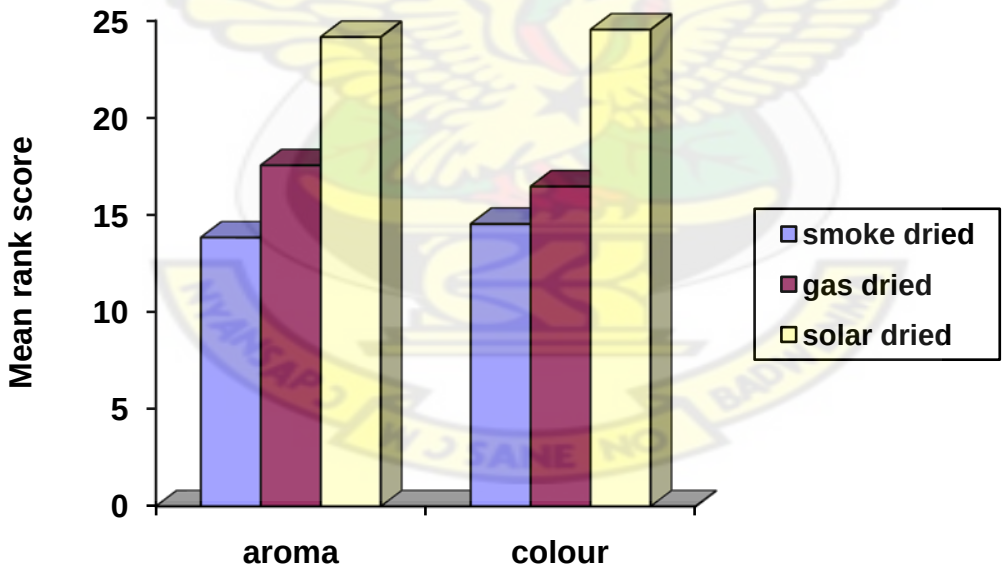
At the end of the storage period of thirty weeks the sample with the highest microbial load was the solar dried samples with 3.19×10^7 cfu/g and 8.11×10^6 cfu/g for bacteria and mold respectively (Tables 3 and 4). Engmann (2005) reported higher microbial loads for both bacteria and mold, about twice as high as the results recorded in this work, at the end of thirty weeks of storage. Smoke - dried snail meat samples were also bought from the open market and the microbial analysis gave 1.96×10^{15} cfu/g and 9.74×10^{15}

cfu/g for bacteria and mold respectively. These commercially processed snail meat samples had not been stored for more than ten (10) weeks and yet contained so high load of microorganisms compared to even the solar dried samples from this work which had the highest microbial load after thirty weeks. The processing procedures, storage and handling regimes that commercially processed snail meat are taken through expose them to microbial contamination.

4.3 Sensory evaluation on snail powder

Sensory evaluation was conducted on the aroma and appearance of the snail meat powder samples and the results are shown in Figure 8.

Figure 8: A graph of sensory evaluation on snail meat powder samples



Shortest peak is most preferred

The smoke dried sample was the most preferred by the panellists in terms of aroma and colour (appearance) as shown in Figure 8. The smoke dried sample had the least mean

rank scores of 13.82 and 14.52 for aroma and appearance respectively. This was closely followed by the gas dried samples with mean rank scores of 17.54 and 16.45 for aroma and colour respectively. The least preferred was the solar dried samples (Table 7, appendix II)

Aroma and colour development are affected by the drying conditions. The high temperature in the smoke dryer led to a non-enzymatic browning of the snail meat and gave the snail meat powder a pleasant golden colour. There was a combined effect of aroma development by heat and deposition of smoke particles on the snail meat. Smoke contains carbonyls, lactones and other compounds which impart flavour to smoked products (Daun, 1979). The presence of certain phenolic compounds such as guaiacol, 4-methylguaiacol and syringol in smoke play an important role in the characteristic flavour of smoked products (Doerr and Fiddler, 1970). These flavouring compounds in combination with the original snail flavour activated by heat gave the smoked snail meat powder samples a desirable flavour which was most preferred by the panellists. Thus, smoke in addition to its preservative effect has an added advantage of imparting desirable flavour to products. However, the choice of wood used to generate the smoke is very important in obtaining an attractive colour and aroma of the product. Hard woods are noted for giving off good quality smoke (Girard, 1992) and in this work charcoal from hard wood and sawdust were used to generate the smoke.

The second most preferred sample was the gas dried sample with a mean rank score of 17.54 and 16.45 for aroma and appearance respectively. The drying temperature was maintained at 80 °C for 8 hours. Browning of the snail meat occurred and a desirable golden colour and aroma of snail were obtained. However, the unique smoke flavour was

absent and this made the smoke dried sample a more preferred choice than the gas dried sample.

For the solar dried sample the drying temperature was low (average of 57 °C) and so not much browning and flavour development occurred. The dry meat looked just like the raw meat and so was least preferred by the panellists.

4.3 Sensory evaluation on 'shito' samples

Sensory evaluation based on the paired preference test was conducted on the aroma and taste of the 'shito' samples and the results are shown in Table 8.

Table 8: Paired preference test results on shrimp powdered 'shito' compared with snail powdered 'shito' samples.

Sensory attribute	Sample	p- value
Aroma	Snail powder	*
	Shrimp powder	**0.043**
Taste	Snail powder	**0.028**
	Shrimp powder	**0.026**

P- Value < 0.05 means most preferred
* Value > 0.05 and thus least preferred

In terms of aroma, the shrimp powdered product was preferred to that of the snail powdered product but there was no significant difference ($p > 0.05$) between the two samples in terms of taste. Thus, snail powder could serve as a cheap source of protein and a very good substitute for shrimp powder which is quite expensive in the production of 'shito' and other food products if the aroma is improved.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The smoke dried samples had the best microbiological (low microbial load) and sensory qualities at the end of the thirty weeks storage period. Smoke drying had two important effects of enhancing the flavour whilst improving the keeping qualities. The study showed that purging of snails had a marked effect on reducing the microbial load even before drying. The smoke dried samples had the least number of microoganisms with 5.15×10^4 cfu/g and 6.64×10^4 cfu/g for bacteria and mold respectively at the end of the thirty – week storage period. The smoke dried samples had the best sensory qualities and were most preferred in terms of aroma and colour. From the results on microbial analyses and sensory evaluation, a combination of purging and smoke drying in addition to hygienic handling and milling are the most innovative methods for processing snail meat powder to obtain products of high microbiological and sensory qualities. The use of charcoal and sawdust in the smoke dryer reduce cost and produce high quality dry snail meat product. All the three improved dryers were efficient in drying and can be used to produce high quality dry snail meat products.

5.2 Recommendations

1. Snail meat should be properly processed before eaten due to the high level of microbial contamination.
2. The high quality snail meat powder could be used as a substitute for shrimp powder in ‘shito’ and other local food products.
3. Further work should be carried out to produce snail meat powdered cubes which could serve as a flavouring additive in other food products.

REFERENCES

Asibey, E.O.A.(1986). Wildlife and Food Security. FAO Forestry Department, Rome. **14**:18-21

AOAC (1990) Official Methods of Analyses, 15th ed., Association of Official Analytical Chemists, Washington D. C.

Ablordeppey, S. D. and Asamoah, B. (2003). Snails, another gem in export trade; Daily Graphic, No. 148751, February 18th, 2003, p.13.

Adams, M.R. and Moss, M.O. (1995). Food Microbiology. Royal Society of Chemistry, UK. pp 18-45.

Ajayi, S.S., Tewe, S.O., Milligan J.K. (1980). Influence of seasonality on aestivation and behavior of the forest African giant land snail, *Archachatina marginata* (Swaison). *Bull Annual Health Proc.* **28**:328.

Akinnusi, O., (1998). A practical approach to backyard snail farming. *Nigeria Journal of Animal Production*, **25**: 85-95

Anon, D. (1969). A guide to capital cost estimation. *Institute of chemical engineers, London,* **32**:56-61.

Arason, S. (2003). The drying of fish and utilization of geothermal energy; the Icelandic experience. International Geothermal Conference, Reykjavik. Paper no. 076.

Asita, A.O. and Campbell, I.A. (1990). Anti-microbial activity of smoke from different woods. *Lett. Appl. Microbiol*. **10**: 93-95.

Baker, R. (1988). Fundamentals of new food product development, Elsevier Science B.V., The Netherlands. pp. 33-34.

Barish, N.W., (1962). Economic analysis for engineering and managerial decision-making, McGraw-Hill, New York. pp. 31- 42.

Beauchat, L.R. (1981). Microbial stability as affected by water activity. *Cereal Foods World*, **26** (7):345-349.

Beckett, W.H., (1964). Akokoaso- A survey of a Gold Coast village: Monograph of Snail Anthropology, 10 London School of Economics. pp. 9-14.

Bender, A., (1992). Meat and Meat Products in Human Nutrition in Developing Countries. FAO Food and Nutrition. Rome, p. 53 - 57.

Bender, A.E. (1978) Food Processing and Nutrition, Academic Press London. pp 59 – 60.

Burton, B. T. and Foster, W. R. (1988). Human Nutrition, (4th ed.). McGraw-Hill Book Company, New York. pp. 38-39, 84, 138-161, 168-170, 194, 221.

Cobbinah, J.R., (1993). Snail Farming in West Africa; a practical guide, technical centre for agricultural and rural co- operation (CTA), Sayee Publishing Company, UK, pp. 18-20.

Daun, H. (1979). Interaction of wood smoke components and foods. *Food Technology*, **63**:85-90.

Doerr, R.C. and Fiddler, W. (1970). Separation of phenols in two phases, *Journal of Agric. Food chem.* **18**: 937 – 939.

Draudt, H. (1963). The meat smoking process: a review. *Food Technology*. **17**:85-90

Ellis, D. F. (2001). Meat Smoking Technology in Meat Science and Applications. pp. 32 - 38

Elmslie, L. J. (1982). The potential for snail farming; New Zealand Farmer. **103**: 30-33.

Engmann, F. N. (2005). Developing an appropriate and cost effective processing method for snail meat. Department of biochemistry and biotechnology, KNUST, Kumasi, Ghana. pp 36, 53, 54, 60.

Fagbuaro, O., Oso, J.A., Edward, J.B. and Ogunleye, R.F. (2006). Nutritional status of four species of giant land snails in Nigeria; *J Zhejiang Univ Sci B.* **7**(9): 686–689.

FAO, (1986). Better farming series: farming snails, economics and social development series, no. 33 and 34, Rome, Italy.

Fleck, H. (1951). Introduction to Nutrition. 3rd Ed , Macmillan, New York. pp. 23 - 25

Gernadi, G.A. (1951). A preliminary report on the biology, ecology and control of the giant African snail (*Achatina fulica* fer.) *Philippine Journal of Agriculture*. **14** (4): 337 - 347.

Girard, J.P. (1992). Technology of meat and meat products, Ellis Harwood Ltd., England, pp.94, 104-108, 153-154, 170-172, 174-185, 187-190, 193, 195-198.

Harris, N. D., Martin, S. R. and Ellias, L. (1975). Bacteriological quality of selected delicatessen foods. Journal of Milk Food Technology, 38: 759-764.

Ihekoronye, A.I. and Ngoddy, P.O. (1985). Integrated Food Science and Technology for the Tropics. Macmillan Publishers, New York. pp. 155-160

James, C. S. (1995). Analytical Chemistry of Foods. Blackie Academic and Professional, Glasgow, U.K. pp 64 - 65

Keey, R.B. (1975). Drying: Principles and Practice. Pergamon Press, Oxford, pp. 1-4, 144-147, 303-307, and 335-336.

Lawand T.A. (1966) Solar Energy **10** (4) 158 – 159

Lehninger, A.L. (1987). Principles of biochemistry, Worth Publishers, New York. pp. 270, 271, 476, 751.

McKee, T. (1996). Biochemistry, an introduction. The McGraw-Hill Companies, Inc. pp 77- 93.

Mead, A.R. (1961). The giant African snail: A problem in economic malacology. University of Chicago Press. pp. 146 – 171.

Muller, H.G.(1988). An Introduction to Tropical Food Science. Cambridge University Press, Cambridge. Pp. 46-47,169-173, 178-181.

Nisbet, R.N. (1974). The life of Archatinidae in London. *Proc Malai Soc Lond.* **41**:1171.

Odaibo, A.B., (1997). Snail and Snail Farming. Nigeria Edible Land Snails. Vol. 1. Ibadan: pp. 1–11.

Oduro, W., Ellis, W.O., Oduro, I. and Tetteh, D. (2002). Meat yield and quality of selected snail species in Ghana, *Journal of Ghana Science Association*. **4** (2) 24-30.

Parker, N.M., (1963). *Chemical Engineer*. **74**(14):115-117.

Perry, H.E. (1963). Chemical Engineers Handbook (4th ed.), McGraw-Hill, New York, pp. 20-24.

Saldanha, T., Gaspar, A., Santana, D.M. da. N. (2001). Composition of meat from the snail (*Achatina fulica*) produced in Iguape, SP. *Higiene-Alimentar*, **15** (85): 69-74.

Schmidt-Nielsen, K., Taylor, C.R., Shkolnik, A. (1971). Desert Snail: problems of heat, water and food. *J Exp Biol*. **55**:385–398

Smith, T.F. and Ojofeitimi, E.O. (1995). Nutrition and diet therapy for health care in Africa, Y – Books, Ibadan, p – 6.

Speck, M.L. (1984) Compendium of Methods for the Microbiological Examination of Foods 2nd edn. American Public Health Association, Washington D.C., U.S.A.

Su, X.Q., Antonas, K.N., and Li, D. (2004). Comparison of n-3 polyunsaturated fatty acid contents of wild and cultured Australian abalone. *International Journal of Food Sciences and Nutrition*, **55**(2): 149 - 154.

Tettey, E.C.T., Osei-Yaw, A. and Hodari-Okae, M. (1997). Studies on the quality of traditionally-smoked dry snail meat (*Achatina achatina*). *Ghana Journal of Agricultural Science*. **30**: 2.

Wall, R., Howard, J.J. and Bindu, J. (2001). The seasonal abundance of blowflies infesting drying fish in south-west India. *Journal of Applied Ecology*, **38**: 338-348.

Watson, J.D. (1971). The nutritive value of some Ghanaian foodstuffs. *Ghana Journal of Agricultural Science*, **4**: 95 - 111

Wilson, N.R.P. (1981). Meat and meat products, Applied Science Publishers, London. pp. 81, 84- 86, 89 – 90, 103 – 108.

Yoloye, V.L. (1984). *Mollusks for Mankind. Inaugural Lecture.* Ilorin, Nigeria: University of Ilorin.

APPENDICES

APPENDIX 1: PROXIMATE COMPOSITION CALCULATIONS

Moisture content determination

Weight of dish = W_1

Weight of dish + wet sample = W_2

Weight of dish + dry sample = W_3

$$\% \text{ moisture} = \frac{W_2 - W_3}{W_2 - W_1} \times 100\%$$

Crude fat content determination

Weight of sample = W_1

Weight of flask = W_2

Weight of flask + fat = W_3

$$\% \text{ fat} = \frac{W_3 - W_2}{W_1} \times 100\%$$

Crude protein determination

The percentage total nitrogen was calculated using the formula below:

$$\% \text{ total nitrogen} = \frac{100x\ (V_a - V_b) \times N_a \times 0.01401 \times 100}{W \times 10}$$

Where

V_a = volume of standard acid used in titration

V_b = volume of standard acid used in blank

N_a = normality of acid

W = weight in gram of the sample.

The percentage total nitrogen calculated was then converted to percentage crude protein by multiplying with the factor 6.25

Thus, crude protein = % total nitrogen x 6.25

Ash content determination

Weight of crucible + sample = W_1

Weight of crucible = W_2

Weight of crucible + ashed sample = W_3

$$\% \text{ Ash} = \frac{W_3 - W_2 \times 100}{W_1 - W_2}$$

Total carbohydrate determination

Total carbohydrate = 100 – (% protein + % fat + % ash + % moisture)

Table 9: Calorific values of foods and energy value determination

Constituents	Calorific value (KJ/g)	Kcal/g
Available carbohydrate	17	4.2
Protein	17	4.3
Fat	37	9.5
Alcohol	29	
Polyols (eg. Sorbitol in dietetic foods)	10	
Organic acids	13	

Source: James, 1995

Energy value (KJ/ 100g) =

(% available carbohydrate x 17) + (% protein x 17) + (% fat x 37).

APPENDIX II: SCORE CARDS FOR SENSORY ANALYSIS

COLOUR

ACCEPTANCE TEST FOR COLOUR OF SNAIL POWDERS USING RANKING

NAME…….

DATE……

INSTRUCTION:

Please observe each of the samples of snail powders from left to right in the order listed below. Assign the sample with the most acceptable colour a rank value of **1**, the sample with the next most acceptable colour a rank value of **2**, and the sample with the least acceptable colour among the three samples a value of **3**. Do not give the same rank to two samples.

CODE	RANK ASSIGNED
…….	……
……..	……
……..	……

AROMA

ACCEPTANCE TEST FOR AROMA OF SNAIL POWDERS USING RANKING

NAME…….

DATE……

INSTRUCTION:

Please smell each of the three snail powdered samples in the order listed below. Assign the sample with the most acceptable aroma a rank value of **1**, the sample with the next most acceptable aroma a rank value of **2**, and the sample with the least acceptable aroma among the three samples a value of **3**. Do not give the same rank to two samples.

CODE	RANK ASSIGNED
…….	……
……..	……
……..	……

Table 7: Sensory evaluation conducted on the snail meat powder samples.

Sensory attribute	Sample	Mean rank score
Aroma	Smoke dried	**13.82**
	Gas dried	**17.54**
	Solar dried	**24.15**
	Asymptomatic significance	0.07
Appearance (colour)	Smoke dried	**14.52**
	Gas dried	**16.45**
	Solar dried	**24.53**
	Asymptomatic significance	0.06

Mean rank score with lowest value is most preferred using Kruskal Wallis Test.

PAIRED PREFERENCE TEST FOR TASTE

NAME ……

DATE ……

INSTRUCTION:

In front of you are two 'shito' samples. Starting from left to right, taste the sample and circle the sample you prefer most. Rinse your mouth after each tasting. You can re- taste a sample after the initial tasting. You must choose a sample.

CODE	CODE
……	……

PAIRED PREFERENCE TEST FOR AROMA

NAME ……

DATE ……

INSTRUCTION:

In front of you are two ‘shito’ samples. Starting from left to right, smell the samples and circle the sample you prefer most. You must choose a sample.

CODE	CODE
……	……