**KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY**

**KUMASI**

**COLLEGE OF AGRICULTURE AND NATURAL RESOURCES**

**FACULTY OF AGRICULTURE**

**DEPARTMENT OF HORTICULTURE**



# EFFECT OF THREE PRE-DRYING TREATMENTS AND TWO DRYING METHODS ON THE QUALITY OF SCOTCH BONNET (*Capsicum chinense*) GROWN IN THE TOLON/KUMBUNGU DISTRICT OF NORTHERN GHANA

**BY**

**ALHASSAN SUALIHU**

**AUGUST, 2012**

# EFFECT OF THREE PRE-DRYING TREATMENTS AND TWO DRYING METHODS ON THE QUALITY OF SCOTCH BONNET, (*Capsicum chinense*) GROWN IN THE TOLON/KUMBUNNGU DISTRIT OF NORTHERN GHANA.



**A DISSERTATION SUBMITTED TO THE SCHOOL OF RESEARCH AND GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE (Phil. POSTHARVEST TECHNOLOGY) DEGREE.**

**BY**

**ALHASSAN SUALIHU**

**AUGUEST, 2012**

## DECLARATION

I certify that this work was carried out by Alhassan Sualihu of the Department of Horticulture, Post-harvest Technology. Kwame Nkrumah University of Science and Technology, Kumasi. All material from which information was sought had been duly acknowledged by their references.



| | | |
|---|---|---|
| ALHASSAN SUALIHU | ……. | …… |
| NAME OF STUDENT | Signature | Date |

| | | |
|---|---|---|
| MR. FRANCIS APPIAH | …… | …… |
| NAME OF SUPERVISOR | Signature | Date |

| | | |
|---|---|---|
| DR. BEN K. BANFUL | …….. | …….. |
| HEAD OF DEPARTMENT | Signature | Date |

## DEDICATION

I dedicate this work to Almighty Allah by whose grace and guidance the successful conclusion of this work has been achieved. I also dedicate this work to my late parent, my wife and friends.

## ACKNOWLEDGEMENT

My sincere thanks goes to Allah the Almighty for having bestowed his mercy upon me and guided me throughout this work.

My second thanks goes to my supervisor, Mr. Francis Appiah for directing me through this work.

My sincere gratitude also goes to my co-supervisor Prof. N. S. Olympio who is a senior lecturer of the department.

I also acknowledge the efforts of Aglanu Dodzie Silvanus for the immense contribution he has rendered towards successful completion of this work.

## ABSTRACT

This study was conducted to assess the effects of different pre-drying treatments (raw steaming, blanching in water and blanching in water containing vegetable oil) and drying methods (sun and solar drying) on the physical and chemical attributes of scotch bonnet (*Capsicum chinense*). The study revealed that blanching technology followed by the two drying methods influenced proximate composition of pepper in varying levels.. The control sample dried under sun contained the following: 50.63% moisture, 5.45mg/100Vitamin C,14.37% proteins, 4.43% fat, 13.93% Ash, 30.45% crude fiber and 22.47% Nitrogen Free Extract. Pepper blanched in water alone and dried under sun contained the following: 12.85% moisture, 4.93mg/100 Vitamin C, 13.73% protein, 3.17% fat, 12.17% Ash, 23.85% crude fibre and 33.93% Nittrogen Free Extract. Blanched pepper in water containing oil and dried under sun contained the following: 6.08% moisture, 6.08mg/100 Vitamin C, 10.97% protein, 15.03% fat, 6.03% Ash, 20.62% crude fibre and 33.50% Nitrogen Free Extract. The control sample dried in solar contained the following: 34.55% moisture, 4.63mg/100 Vitamin C, 13.43% protein, 2.87% fat, 13.87% Ash, 25.44% crude fibre and 29.74% Nitrogen Free Extract. Pepper blanched in water alone and dried in solar contained the following: 12.69% moisture, 4.07mg/100 Vitamin C,11.98% protein, 3.17% fat, 16.17% Ash, 23.50% crude fibre and 32.03% Nitrogen Free Extract. The pepper sample blanched in water containing oil and dried in solar contained the following: 6.98% moisture, 4.83mg/100 Vitamin C, 11.15% protein, 12.27% fat, 5.77% Ash, 20.36% crude fibre and 35.30% Nitrogen Free Extract. This study revealed that blanching in water with oil and drying scotch bonnet (Capsicum chinense) resulted in good moisture content for storage and maintenance of its nutritional level.

## TABLE OF CONTENT

**Content** **Pages**

## LIST OF TABLES

## LIST OF FIGURES

# CHAPTER ONE

## 1.0 INTRODUCTION

Hot pepper belongs to the Family Solanacea with Capsicum as a genus which dominated the cultivated species. The genus Capsicum comprises 20-30 species (Norman, 1992). Modern taxonomy recognizes 5 major species including *Capsicum annum*, *Capsicum frutescens*, *Capsicum Chinense jacquin*, *Capsicum pendulum willdenow* and *Capsicum pubescence* (Greenleaf, 1986).

In Ghana the cultivated peppers documented by Norman (1992) are *Capsicum frutescens*, *Capsicum annum* and *Capsicum Chinense jacquin*. The plant is said to have been discovered by Columbus in tropical America where it spread to Europe and subsequently to Africa (Sinnadurai, 1992). According to Tindall (1983) South America possibly Peru or Mexico may have been the second centre of origin and diversity. Peppers are now widely grown in most countries with warm climates. It is suggested that hot peppers in West Africa came from either other African countries, overseas or through hybridization (Yanney-Wilson, 1960).

Peppers as spices are very useful source of food providing high levels of nutrients such as vitamins, protein, fats, energy and other mineral source (Norman, 1992; Tweneboa, 1989). The bright colors, flavor pungency of pepper contribute to the aesthetic taste value of meals (Norman, 1992; Bosland and Votava, 2000).

Hot pepper generally has a biting and hot taste due to the mixture of seven related alkaloids; capsaicin is most prevalent. Capsaicinoids are mainly found in the seeds and placental area in some cultivars while found in all parts of others. Capsaicin is so potent that it can be tasted in concentrations as low as one part per million. Due to the concentration of capsaicin, even handling or cutting the pepper can irritate the skin (McMahon *et al*., 1999).

Many cooks have experienced a burning sensation when the juice of hot pepper (chilies) touches the skin. It appears that both hot temperatures and capsaicin trigger the same pain-sensing nerve fibers and explains why we perceive the taste of a chili pepper as hot. The potency of capsaicin has been utilized for different applications, for instance, as a pepper spray by police to subdue unruly persons.

Many Hungarian, Italian, Mexican, Cajun, Indonesian, Indian and Oriental dishes all utilize some types of capsicum pepper or spice. It can also be grown as ornamentals for their colorful fruits. For instance, it is a tradition in New Mexico to string red chilies into ristras, which are hung near the entrance as a symbol of hospitality (McMahon *et al*., 1999). Considerable research has focused on peppers' antioxidant nature in fruits for protection from cancer (Bosland *et al*., 2000). Application of capsaicin obtained from peppers as an analgestic cream either eventually desensitizes or may actually destroy the nerve fibers. Thus physicians use such creams to apply on patients to relieve the pain of arthritis, shingles, cluster headaches and other ailments (McMahon *et al*., 1999).

In Ghana scotch bonnet (*Capsicum chinense*) is an economic crop. It is cultivated mainly by peasant farmers in many regions including Northern region to generate income in a short period to meet their economic needs.

## 1.1 PROBLEM STATEMENT

Scotch bonnet (*Capsicum chinense*) though a perennial, tends to be an annual. The crop is always used in the preparation of local dishes such as soup, stew, 'Hausan koko' and notably 'shitto' (pepper sauce).



In view of the seasonal nature of the crop, the fresh fruits are only available from August to October and become scarce in December till the next season. Market women have to travel to Navrongo to buy fresh pepper fruits for the market in Tamale. Dried pepper fruits are not patronized well as a result of poor quality although it last barely for only one month.

## 1.2 JUSTIFICATION

Pepper is consumed by most homes and its demand keeps on rising. However, since it is seasonal in the region there is the need to identify appropriate technologies that could help in making pepper available in the region all year round. Pepper has been major fruit trades in the region thus its development will increase the per capita income of peasant farmers there by improve their standard of living. Of late, less attention has been given to the potential demand for the scotch bonnet and how their production can be integrated into food production programmes.

Findings from the study can be used to encourage farmers to cultivate the crop on large scale in the Northern region. The study can also be used as source of information for the development of educational programmes to increase the public awareness of the value of scotch bonnet (*Capsicum chinense*) in our nutrition.

## 1.3 OBJECTIVE OF THE STUDY

### *1.3.1 MAIN OBJECTIVE*



The main objective of the study was to identify the optimum condition for drying scotch bonnet (*Capsicum chinense*) in the Northern Region of Ghana.

### 1.3.2 SPECIFIC OBJECTIVES

**The specific objectives are:**

1. To assess the effect of sun and solar drying on physico-chemical attributes of pepper
2. To evaluate rate of drying pepper in the two different drying systems
3. To evaluate the effect of different pre-drying treatments on the shelf life of dried pepper

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

Pepper (*Capsicum* spp.) is one of the most varied and widely used foods in the world. From the various colours to the various tastes, peppers are an important spice commodity and an integral part of many cuisines. Peppers originated in the Mexico and Central America regions. Christopher Columbus encounters pepper in 1493 and, because of its pungent fruit, thought it was related to black pepper, *Piper nigrun*, which is actually a different genus.



Peppers were important to the earliest inhabitants of the western hemisphere as much as 10,000 to 12,000 years ago. Plant remnants have been found in caves in the region of origin that date back to 7,000B.C. The Incas, Aztec and Mayans all used pepper extensively and held the plant in high regard. Many of the early uses of pepper were on medicinal purposes. Pepper has been credited with much number of useful cures and treatments.

Virtually every country in the world produces pepper. The bulk of pepper produced in the United States is sweet pepper, but hot peppers dominate in other countries. Globally, pepper production exceeds 14 million metric tons. California is the leading producer of sweet peppers in the United States. Fresh market production is a large part of the U.S. market, although processed peppers are common in all parts of the world as dried, pickled or otherwise processed products.

Pepper production has increased in recent years worldwide. That could be at least in part because of the high nutritional value of pepper. One medium green bell pepper can provide

up to 8 percent of the recommended daily allowance of Vitamin, 180 percent of Vitamin C, 2 percent of calcium and 2 percent of iron. Additionally pepper contains significant amounts of the A and B vitamins.

All peppers are members of the *Solanacea* family, which also include tomato, tobacco, eggplant and Irish potato. There has been much debate over the years as to how many species of Capsicum truly exist. The number has fluctuated over the centuries from 1 to 90. Currently five species are recognized as domesticated. Among these are *Capsicum annum*, which includes the bulk of cultivated types including bell, yellow wax, cherry, ancho, cayenne, jalapeno and Serrano. Capsicum chinense include the habaeros and Scotch bonnet. Tobacco is the most notable variety in the *Capsicum frutescens* species. The only important variety in the *Capsicum battacum* species is the Yellow Peruvian Pepper. *Capsicum pubescens* includes 'manzano' and 'peron' pod types. The classification of species will obviously continue to evolve in the future. There are an additional 20 or more species of wild types.

A phenolic compound called capsaicin is responsible for the pungency in peppers. The compound is related to vanillin. It is not located in all parts of the fruit, and various cultivars differ markedly in their content of this chemical.

According to American chemical society (2006), capsicum plants are among the most consumed spices throughout the world. These fruits contain capsaicinoids, a family of compounds that give them the characteristic pungent taste. The two major capsaicinoids,

capsaicin and dihydrocapsaicin are responsible for up to 90% of the total pungency of pepper fruit.

A simple, highly selective and reproducible liquid chromatography is used. Electro spray ionization/time-of-flight mass spectrometry method has been developed for the direct and simultaneous determination of capsaicin and dihydrocapsaicin in capsicum fruit extracts. Chromatographic separation of capsaicin and dihydrocapsaicin was achieved with a reversed phase chromatography column, using a gradient of methanol and water. Quantification was done using as an internal standards (4, 5-dimethoxybenzyl)-4-methylocatamide, a synthetic capsaicin analogue not found in nature.



Analytic recoveries found were 86 and 93% for capsaicin and dihydrocapsaicin respectively. The method developed has been applied to the identification and quantification of capsaicin and dihydrocapsaicin in fruit extracts from different capsicum genotypes and concentrations found ranged from 2 to 6639mgkg-1(Journal).

Pepper is considered a self- pollinated crop although some out crossing will occur. Although grown as an annual crop due to its sensitivity to frost, pepper is actually a herbaceous perennial and will survive and yield for several years in tropical climates.

Peppers grow well in warm climates with a relatively long growing season. Most cultivated peppers require around 75 days from transplanting to first harvest and can be harvested for several weeks before production wanes. Ideal temperatures for pepper growth are in the

range of 75-89 degrees F during the day and 65-75 degrees F at night. Significantly higher or lower temperatures can have negative effects on fruit set and quality.

Pepper production is complex as it requires highly intensive management, production and marketing skills, and a significant investment. Expertise in the areas of cultural practices, soils and fertility management, pests control, harvesting, post-harvest handling, marketing, and farm record keeping is crucial to profitable production (George E. Boyhan and Terry W. Kelly, 2009).



## 2.1 SOIL REQUIREMENTS

Peppers can be produced on a wide range of soil types. They grow best, however, in deep, medium textured sandy loam or loamy, fertile, well drained soils. Thus, water logged soils should be avoided and crops should be away from fields that have had solanaceous crops within the past 3 to 4 years.

Proper tillage is crucial for adequate soil management and optimal yields of pepper. Land preparation should involve enough tillage operation to make the soil suitable for seedling or transplant establishment and to provide the best soil structure for root growth and development. The extent to which the root systems of pepper plants develop is influenced by the soil profile. Root growth will be restricted if there is a hard pan, compacted layer or heavy clay zone. Peppers are considered to be moderately deep rooted and, under favorable conditions, roots will grow to a depth of 36 to 48 inches. But the majority of roots will be in

the upper 12 to 24 inches of soil. Since root development is severely limited by compacted soil, proper land preparation should eliminate or significantly reduce soil compaction.

Compaction pans are present in many soils. They are formed principally by machinery and, when present, are normally located at or just below plough depths. Even though compaction pans may be only a few inches thick, their inhibitory effects on root growth can significantly reduce pepper yields. If a compaction pan exists just below or near moldboard plough depth, this hard pan can be disrupted by sub soiling to a depth of 16 to 18 inches to allow the development of a more intensive root system.



Peppers are usually transplanted into plastic mulch on raised beds. A raised bed will warm up more quickly in the spring and therefore may enhance earlier growth. Since peppers do poorly in excessively wet soils, a raised bed improves drainage and helps prevent water logging in low areas or poor drained soils. Raised beds are generally 3 to 8 inches high. However care should be taken as peppers planted on raised beds may also require more irrigation during drought conditions.

## 2.2 VARIETIES

There are numerous commercially available varieties which perform differently under various environmental conditions. Selection of varieties is on the basis of marketable yield potential, quality, market acceptability and disease resistance or tolerance. However, when selecting a variety, yield should not be the only selection criteria. Plants need to produce adequate foliage to protect fruit from sun burns. Market preferences for fruit size and colour

should also be considered. Disease resistance is more important with diseases for which there are no other good management options. Basically, a variety must be adaptable to the area, produce a competitive yield and be acceptable to buyers.

All commercially important bell peppers belong to the genus *Capsicum annuum*. Some pungent varieties encompass other species, for instance, Naga King Chili in Naga Morich. In Nagaland it is grown in districts of Kohima, Mon and Peren. Its fruits form an essential ingredient of the Naga kitchen. It grows at the height of 120 cm bearing up to 150 fruits. The people of Nagaland have been eating it for delicacy. Its ordinary pungency level and irritating properties it has also been used as lachrymatory agent (a chemical compound that irritates the eyes to cause tears, pain, and even temporarily blindness). Nagas are known to have used this chili as a biological weapon in ancient warfare to get rid of enemies and also used to smoke out fox and rodents in their fields.

Another example of the chili peppers is the Espelette Basque Chili pepper produced and managed by the department of Fraud which guarantees the origin of the Espelette Basque Chilli pepper pods, powder and seeds. It is more aromatic and sweet than hot. Espelette Basque Chili peppers are tied with string and the strings of pepper are hung in the kitchens to dry. Once dried it is ground in to powder which is very much prized around the world in the home and in many restaurant kitchens. In the kitchen, this spice substitute is for providing pepper to meals. The chili is used in Basque Cuisine to give taste to the simplest dishes such as grilled sardines or salads-sprinkled on grilled goat or sheep cheese, and the Basque Chili flavours.

In northern Ghana, three types of hot peppers are cultivated and consumed. These are the (i) tiny very spicy pepper which is a local landrace and popularly called bird chilli, (ii) the finger-like chilli (*Capsicum frutescens* L) and the very spicy heart-shaped variety (*Capsicum chinense* Jacq). With a monomodal rainfall pattern most of the peppers are cultivated during the rainy season. A small percentage, however, is cultivated under irrigation during the dry season. Owing to its ability to sun-dry for future use, *C. frutescens* is almost absent from the market during the harvesting season whilst there is a glut of *C. chinense* due to its inability to sun dry. On investigating why there is no sun-dried *C. chinense* on the market, a woman processor informed the authors that *C. chinense* could only be dried in an oven (after bread baking) since it is very difficult to dry. A preliminary study revealed that the woman processor was right. A small sample the authors bought and sun dried in November 2004 could not dry after three weeks of continuous sun drying. The pepper just continued to shrink. Some even turned white. A blanched sample dried well and maintained fairly its colour after eight (8) days. Hence blanching could have solved the problem.

Usually, pepper processors in northern Ghana do not blanch peppers before drying. The harvested products are just spread in the sun and allowed to dry. Besides taking over two weeks to dry the pepper contracts all sorts of dirt and impurities. Besides that the dried produce absorbs moisture and loses its colour and crispness when the rains start and humidity increases due to the enzymes that are still active. One need not ask why the pepper is not blanched before drying. Wood fuel is very hard to come by. It is always a pathetic sightseeing women and girls struggling to get wood fuel for domestic use. Therefore fuel to blanch pepper is

out of the question. There is therefore the need to look for an efficient but cheap source of energy to enable pepper processors easily blanch and dry all sorts of peppers cultivated.

During the harvesting season in 2004 a mini bag of the *C. chinense* was sold at ¢30,000.00. During the lean season in early 2005 a bag of dried *C. frutescens* was ¢450,000.00. Under all conditions *C. chinense* yields about twice that of *C. frutescens* (De Lannoy, 2001), but because the former cannot be dried, cultivation is lower than the latter. If both peppers could be dried farmers would be more inclined to cultivate the one with the higher yields. That means a doubling of their income. Helping farmers and women processors with efficient, reliable and cheap method of drying all peppers could more than double their income from pepper production. Farmers too will increase the size of their farms if they get a way by which they could process their peppers efficiently and sell during the lean season. Ability to dry both peppers too will remove the glut always experienced during the harvesting season (Owusu *et al.*, 2008).



## 2.3 SOILS AND FERTILITY MANAGEMENT

Fertility management is impacted by cultural methods, tillage practices, and cropping sequences. A proper nutrient management programme takes into account native soil fertility and residual fertilizer. Thus, the first step in an appropriate fertilizer management programme is to properly take a soil test.

Recommending a specific fertilizer management programme universally for all pepper fields would result in applications that are inefficient and not cost effective. In addition to crop

nutrient requirements and soil types, fertilizer recommendations should take into consideration soil pH, residual nutrients and inherent soil fertility. Therefore, fertilizer recommendations based on soil test analyses have the greatest potential for providing peppers with adequate but not excessive fertility.

Adjusting the soil to the appropriate pH range is the first consideration for any fertilizer management programme. The soil pH strongly influences plant growth, the availability of nutrients, and the activities of microorganisms in the soil. It is important to keep soil pH in the proper range in order to produce the best yields of high quality peppers. Soil test results indicate soil pH levels and also provide recommendations for any amounts of lime required to raise the pH to the desired range. The optimum pH range for pepper production is 6.2 to 6.8. Continuous cropping and application of high rates of nitrogen reduce pH at an even faster rate. In addition to raising pH, lime also adds calcium and, with dolomite lime and magnesium to the soil.

In addition to lime application, pre-plant applications and in-season supplemental applications of fertilizer will be necessary for good crop growth and yield. Research shows that broadcasting over the entire field is usually less effective than banding. An acceptable alternative to field broadcasting and one that is most often used with plastic mulch production is the 'modified broadcast' method, where the pre-plant fertilizer containing a portion of the nitrogen and potassium, and any recommended phosphorus and micronutrients, are broadcasted in the bed area only.

## 2.4 HARVESTING AND HANDLING

Pepper harvesting time is usually determined by the fruit colour required for marketing. Bell [sweet] peppers for the fresh market should be harvested immature while fruits are firm, shiny in appearance, and have a fresh green calyx and stem. Irregular shape does not detract from edible quality, but it reduces eye appeal, which may lower market acceptability. Peppers having soft, pliable, thin flesh and pale green colour (for certain varieties) are immature for harvest.



Fruit injuries to the fleshy wall increase susceptibility to decay and should be eliminated or minimized. Decay may appear as water-soaked, bleached or blackened areas that may or may not be noticeably sunken into the pepper wall. All peppers can be classified as having either 'sweet' or 'hot' (pungent) flesh. Bells are sweet while chili types are hot. Chili peppers are usually green when immature and turn red, yellow or orange at maturity. Thus harvest time depends upon market preference. Pungency is caused by an oily substance called capsaicin, located in yellow sacks or pustules on the inside wall of the pepper pod. As long as these oil glands are not broken, a hot pepper will remain mild. Good harvesting management is thus essential, since pepper plants have brittle stalks, care must be taken by workers to remove fruit from the plant with stalks attached. Peppers with intact stalks are more resistant to bacterial soft rot than those with torn or partial stalks.

Maintaining good sanitation throughout harvesting and handling peppers is extremely important. Human pathogens causing food borne illness can be transmitted by direct contact from infected employees or animals, or through contaminated equipment and water. Once a

vegetable is infected, pathogens are difficult or impossible to remove without some form of heat treatment [blanching]. Reducing the risk of human pathogen contamination to fresh pepper can be ensured by use of cleaned and sanitized field containers and harvest aids (knives or gloves). Likewise, training, monitoring and enforcement of employees hygiene practices, such as proper hand washing after using the toilet is necessary (W. Hurst, 2009).

Peppers can be preserved in the fresh form by refrigeration or dry through the various drying methods such as sun drying, solar drying, oven drying and electric drying. They can also be preserved by dehydration through freeze-drying or spray-drying. However, drying of peppers has been the most common practice in the tropics for preservation or storage.



Drying of food is the oldest form of food preservation. Drying in the sun is a common practice, but it will bleach the fruits. Dehydration is an intermediate step in turning raw agricultural products into retail products. Dehydrating foods reduces the moisture in them to levels that inhibit the microbial growth that causes deterioration. Food dehydration is safe because water is removed from the food and so mold and bacteria cannot grow on it to cause spoilage (Appiah, 2009). Of all food preservation methods, drying received the most widespread and enthusiastic publicity in recent years. For dry chili peppers, it is important to preserve red colour of mature fruits. Whole chilies can be dried by spreading on rectangular aluminium trays at 5kg/m² (Levetin, 1999).

The use of dehydrated products has increased due to its advantages over other preservation techniques. The advantages include;

i. Weight of a product is reduced to ¼th to 1/9$^{th}$ of the original or fresh weight and thus cost of its transport is reduced,

ii. Due to reduction in bulk of product, it requires less storage space,

iii. No preservative is added for its preservation,

iv. Nutrient concentration is very high per unit weight of dried product and

v. Cost of processing is very low as there is less labour and capital investments.



## 2.5 BACKGROUND OF THE STUDY

### 2.5.1 DEFINITIONS

Drying refers to the process of removing moisture from produce to acceptable levels that inhibit microbial growth so as to prevent spoilage. It is carried out through the application of heat or at ambient conditions. During drying under ambient temperatures, the produce is spread thinly over pavement, tarpaulin or plastic sheet and exposed to the sun. Turning has to be done regularly to avoid sun burns or scorching of produce. When the water is forced out of the produce, it is termed as dehydration. Drying of produce is affected by the following factors:

i. Composition of raw material,

ii. Size, shape and arrangement of stacking of produce,

iii. Temperature, relative humidity and velocity of air and

iv. Pressure and heat transfer to surface.

### 2.5.2 THE DRYING PROCESS

When drying food, temperatures should be monitored closely at the beginning and end of drying period. Temperatures too low may result in the growth of bacteria on the food. Whereas high temperatures results in the food being cooked instead of dried. If the temperature is too high in the initial phase, a hard surface develops on the produce. This prevents the removal of moisture from the interior portion of fruit and the moisture trapped inside the food material. High temperatures at the end of drying period also cause food to scorch losing its flavor and nutritive value. High temperatures may be used at the beginning, but reduced considerably as food begins to dry. Turning of the food is essential, thus rotating the trays while the food being dried is necessary.



### 2.5.3 PRESERVATION METHODS

**A.** Blanching; it is a thermal treatment given to plant material for inactivating enzymes and killing plant tissues to prevent enzymatic and microbial deterioration. Blanching is required prior to dehydration of many commodities. This is so because, temperatures associated with dehydration are insufficient to inactivate enzymes within the product and the enzyme activity is not controlled by reduced moisture content.

Moisture or water is usually determined by the loss in weight that occurs in a sample upon drying to a constant weight in an oven. The official methods involve drying a representative sample in an oven at 95$^{o}$C – 110$^{o}$C for 24hours, for 2 hours at 135$^{o}$C or 60-70$^{o}$C for 48hours. The moisture content of some foodstuffs which contain other volatile compounds, particularly short-chain fatty acids or fat or fatty products

cannot be determined by these methods. Blanching thus prevents discolouration, softening and off flavor development during subsequent storage.

**B.** Sun drying; this depends on the weather temperature and relative humidity outside. In hot dry climates, sun drying may be successful. Its advantage is the low cost. Only drying trays, netting to protect the products and time are required.

**C.** Solar drying; it is a modification of sun drying in which the sun's rays are collected inside a specially designed unit with adequate ventilation for removal of moist air. Temperature is increased usually to 20 to30 degrees higher than the open air sun light, which results in a shorter drying time.

Lack of control over weather is the major problem with both sun and solar drying. Under solar drying, black-painted trays, solar rays' collector and mirrors are required to increase solar energy and accelerate drying.

The main reasons for drying peppers is simply to enable one keep them for a long time. This can be done through the following:

**D.** Drying pepper with dehydrator; to dry pepper using dehydrator, the following procedure is followed:

1. Slice them in half, if desired; remove the seeds, stem and membranes from each fruit.
2. Lay the halves, cut side down, in single layers on the dehydrator screens

3. Take the dehydrator to a well-ventilated area. The fumes from very hot peppers will make one's eyes water, and since this process can take several days, make sure the location is closed off and well ventilated. Outdoor would be even better, if possible.
4. Let the pepper sit in the dehydrator for several days at about 100 degree °F, checking to see how they are progressing. They must be very dry before storage, as any moisture left over will invite mold and parasites.

**E**. Oven drying; this is carried out by preparing the pepper the same way as using a dehydrator. The seeds will be removed and the arranged directly on the oven racks, if desired, or on baking sheets followed by the steps below:

1. Put the pepper in the oven and heat to 100 to 135°F. Leave the oven door open a bit to provide air circulation.
2. If baking sheets are used, turning of the pepper frequently should be done to provide even drying.
3. Allow the pepper to dry well, with no discernible moisture leftover.

**F.** Air drying; to dry peppers in the air, leave them whole and the stems attached, followed by:

1. Using a long, sharp needle and strong thread or fishing line, string the pepper together. Leave enough space for the air to circulate between each pepper fruit.
2. Hang the stringed peppers in a warm, dry place, preferably in the direct sun light.
3. The peppers may take a few weeks to dry completely. If the seeds are kept intact, this method is used.

Peppers dried in the dehydrator or oven will lose some of their colour and the seeds, while air-dried ones will retain both their colour and their very spicy seeds. When they are completely dried, they can be stored in an airtight container or zipped plastic bags in a cool, dry place. Dried peppers can be ground and used as spices or soaked in water to rehydrate and used in soup and sauces.

### 2.5.4 PROSPECTS AND CONSTRAINTS



Drying of pepper is particularly suitable if dry weather with high temperatures and low humidity can be sustained. Where the weather is cold (less than 85°F) and there is not sufficient photoperiod (3-4 day of consecutive sun exposure) and high humidity [above 60%], sun drying or solar drying is not possible. Low temperature or high humidity encourages microbial growth and possible production of mycotoxins such as aflatoxin.

Hot pepper is attacked by insect pests such as aphids, cucumber beetles, leaf miners, pepper maggots and pepper weevils. They can cause damage to the crop which affects fruit quality and thus need to be controlled appropriately. Insect pests can damage pepper throughout the growing season, but severity varies with location and time of year. The severity of damage to pepper by insect pests is largely due to abundance of the pests, which is related to environmental conditions. Knowledge of pests' habits, careful pest monitoring, and timely use of effective control measures does enable growers to avoid or at least reduce the damage to fruits (A. Sparks, 2009).

Diseases such as anthracnose, bacterial spot, damping off and blight attack the crop on the field which affects drying quality. Sunscald is a result of pepper fruit exposure to long durations of intense sunlight. Exposed areas of the fruit become light-coloured and slightly wrinkled tissue. Good plant canopy will normally provide adequate shade to fruit and prevent sunscald. Hand picking of affected fruits can also be done before drying.

The problem of blossom drop in pepper is primarily associated with high temperatures, particularly when night temperatures are above 70 degrees F. Other stress factors such as inadequate moisture can also contribute to blossom drop. Fruit load can also affect blossom retention. As fruits are set on a plant, additional flowers may drop or abort because the plant does not have sufficient resources to continue setting fruit (G. Boyhan and W. Terry Kelley, 2009).

Blossom-end rot is a physiological disorder of several vegetables including tomato, watermelon, squash and pepper. It is characterized as a dark brown to black necrotic region on the blossom end of developing fruit. Fruit losses can vary from negligible to economically devastating levels, depending on variety, weather, culture and soil type. The first external symptom to appear is a small water-soaked spot at or near the blossom end (opposite the stalk) of the pepper. The water-soaked spot eventually enlarges with time and becomes dry, sunken, flattened, brown or black and papery or leathery. Secondary attack by fungal or bacterial organisms may cause fruit rots.

Although the necrotic tissue associated with this disorder is calcium deficient, the development of the disorder has more to do with water relations. Calcium moves passively in plants, primarily in the xylem in the transpiration stream. Once incorporated into plant tissues, calcium is relatively immobile in the plant. Very little calcium moves downward in phloem tissue. Since calcium moves into roots through unsuberized tips of root hairs, any damage that occurs to these cells can interfere with calcium uptake. This can cause problem particularly during periods of fruit development. During periods of rapid transpiration, as occurs during very hot weather, calcium may rapidly move to and accumulate in the growing tips but not move to developing fruit.



Pepper stippling is another physiological disorder that is also associated with calcium deficiency. Small spots occur inside the fruit wall as the pepper reaches maturity. These spots are brown or black and result in green or yellow spots occurring on the fruit surface. Potassium deficiency may also play a role in this disorder.

Sunscald is yet another problem when ripening pepper fruit is not adequately shaded by leaf cover. Large sections of the exposed fruit can develop grey or brown paper-line areas. These areas render the fruit unwholesome due to the poor colour development. Selecting varieties that produce sufficient leaf canopy, preventing diseases and insects that defoliate the plant, and maintaining adequate fertility, particularly after fruit set, are important considerations in controlling this problem.

The dry season in the Northern region is usually from November to March. It is influenced by the dry North-Easterly (Harmattan) winds while the rainy season is influenced by the moist South Westerly winds. The mean day temperatures range from $33^{o}$ C to $39^{o}$ C while mean night temperature range from $20^{o}$ C to $22^{o}$ C. The mean annual day sunshine is approximately 7.5 hours. Farmers who produce their pepper during the months of October and November thus stand the chance of receiving better climatic conditions for drying their products.

# CHAPTER THREE

## 3.0 MATERIALS AND METHODS

### 3.1 BACKGROUND OF STUDY AREA

The study was carried out in the Tolon/Kumbungu district where the production of the crop is more pronounced. Tolon is the district capital located 24km west of Tamale.

The people of the study area cultivate such crops as yam, millet, maize, rice, sorghum, cowpea, groundnuts, cotton, tobacco, cassava and vegetables. Land use in the area is threatened seasonally by problems, which include:

i. Reduction in the fallow periods, due to increased pressure on land as a result of increased population,
ii. Erratic and unpredictable rainfall pattern and
iii. Annual bush fires that lead to the loss of most of the vegetative cover.

The dry season is influenced by the dry North-Easterly (Harmattan) winds while the rainy season is influenced by the moist South Westerly winds. The mean day temperatures range from $33^{o}$ C to $39^{o}$ C while mean night temperature range from $20^{o}$ C to $22^{o}$ C. The mean annual day sunshine is approximately 7.5 hours. The hot pepper (*Capsicum chinense*) is produced in almost all the various districts of the Northern region and transported to the regional capital, Tamale Metropolis for sale.

## 3.2 DATA COLLECTION

The primary data were collected by direct field observations and group discussions with members of the community. These were used as they help prompt people bring to light more information about the topic under discussion. They also provide enabling environment for the community members to interact freely with researchers.

The *Capsicum species* is of various varieties. The two major ones are the chili (*Capsicum frutescens*) and (*Capsicum chinense*) varieties. The study was carried out on the scotch bonnet (*Capsicum chinense*) as it has received much attention in recent times in the community. The fruits are berries that vary considerably in shape, size and colour among the various varieties. The immature fruits are green, and the mature ones vary in colour from yellow to purple to bright red and in shape from long and narrow to almost spherical and heart-shaped.



## 3.3 SOURCE OF SAMPLE

Samples of hot pepper fruits were taken from one farmer who harvested them from the same field and treated in three ways; blanched with the addition of oil, blanched without oil, and the control. A total of three thousand, six hundred fruits of uniform weight and colour were sampled for both destructive (proximate) and non-destructive (weight) analysis. One thousand, two hundred fruits were blanched with the addition of oil, one thousand, two hundred fruits were blanched without oil and another one thousand, two hundred fruits were taken for control. The samples were dried in solar drier and under the direct sun shines separately and simultaneously so as to obtain the best means of drying among them.

## 3.4 LOCATION OF THE STUDY

The study was carried out at the premises of Horticultural Department in the Kwame Nkrumah University of Science and Technology. Facilities of the laboratory at the department were used for measurements of quantities, size of sample and climatic conditions during the application of the treatments. The proximate analysis was carried out using standard methods of AOAC (1990) and the Soxhel extraction technique described by Shir Law (1967) according to Nwodo *et al.*, 2012. This was done at the Faculty of Renewable Natural Resources, Department of Wildlife and Range Management.



## 3.5 TREATMENTS

The various treatments of the study included blanching, blanching in addition of oil, the control and drying the samples, one half from each treatment in solar drier and the other half under the direct sun shines.

## 3.6 APPLICATION OF TREATMENTS

1. Blanching; three liters of water was boiled in to which four hundred fruits of approximate weight (125g) were placed and covered to blanch for 5 minutes. The same was repeated three times to avoid biasness.
2. Blanching with the addition of oil; 1.5 liters of water was boiled with 500ml of oil (shear butter) added to blanch four hundred fruits of weight 125g approximately for 5 minutes. This was also replicated three times. The process is the same as blanching only that, the oil is added to prevent the produce from absorbing the moisture as the steam condenses over the produce.

3. The sample for the control was also made up of four hundred fresh pepper fruits in triplicate and dried under the various drying methods employed.

The two drying methods employed were solar drying and under the direct sun shines.

a) Solar drying; solar driers were constructed so the sun shines upon a solar collector (a shallow box, the inside painted black, topped with a pane of glass) heating air which then moves upward through a stack of four to six trays loaded with produce. Temperature is increased steadily usually to 20 to30 degrees higher than the open air sun light, which results in a shorter drying time.

   The produce was checked each day and moved under shade or cover if rain threatens. Aluminum foil was utilized to reflect the sun onto the drying trays. Plastic sheet was used to trap some of the heat and speed up the drying period.

b) Sun drying; the samples were dried under the direct sun by spreading them thinly on concrete floors. Its advantage is the low cost. Only drying trays, netting to protect the products and time are required.



## 3.7 EXPERIMENTAL DESIGN

The experiment was carried out using 3×2 factorial experiments. Pre-drying treatments (blanching, blanching with the addition of oil and no blanching) followed by subsequent drying under solar and the direct sun shines were carried out. The drying period, temperatures both ambient and in the driers and their relative humidity were measured.

## 3.8 REPLICATIONS

Each treatment was replicated three times. Four hundred fruits were blanched in water alone in three badges, while another four hundred fruits were blanched in water containing oil also in three badges. One thousand, two hundred fruits were taken for control. One half of the fruits under each treatment were dried in solar drier while the other halves were dried under the direct sun shines.



## 3.9 PARAMETERS STUDIED

The parameters studied included mould growth, moisture content and change in weight, and proximate of nutritional values (vitamin C, crude fiber, fats, protein, and ash) of the crop. Standard procedures such as official method of AOAC (1990), Kjeldal method (Nwodo *et al.*, 2012) and Soxhel extraction technique described by Shir Law (1967) were used to assess the physical and functional properties of the pepper (*Capsicum chinense*) as follows:

1. **Determination of weight loss**

Weight loss was determined according to Banaras *et al.*, (2005) by weighing individual fruits and calculating total and daily percent weight loss.

Samples of the fresh pepper fruits were weighed and recorded before they were put in the driers. A routine daily weight of the pepper fruits were then taken from day 1 up to 12 days of drying till a constant weight value was realized. The results were then tabulated as under the results chapter.

2. **Determination of mould growth**

The initial mould contamination was determined by an analysis of samples each containing 10g of whole pods (Seenappa *et al*., 1980). Each sample was homogenized in a Waring blender with distilled water and appropriate dilutions were plated in potato dextrose agar (PDA) (Difco. Detroit, Ml 48232) amended with 30mg/L of tetracycline hydrochloride. The total propagule count was obtained after incubation for three days at 28°C. The plates were then incubated for an additional 4days, after which the predominant colonies were subcultured on potato dextrose agar and later identified according to the group system of Raper and Fennell (1965). Samples of the three treatments were then carefully observed daily for mould growth on each sample up to 12 days. Values of records were then tabulated as can be seen under the next chapter among the results.

Determinations of proximate analysis were as follows

1. **Determination of Moisture Content**

The moisture content of the pepper was determined according to the official method of the AOAC (1984). Five grams of granular sample was weighed in to a crucible and placed in to an air oven at 105°C for 24 hours. The crucible plus the sample was allowed to cool in desiccators and reweighed afterwards. The moisture content was then calculated using the formula:

(A + B) – A = B

(A + B) – (A + C) = B - C = D therefore; % Moisture = D/B x 100

Where A = weight of crucible, B = weight of sample, C = weight of dry sample and D = weight of moisture.

## 2. Determination of Vitamin C

The Vitamin C content of the dried pepper was determined according to the official method of the AOAC (1990).

An amount of 0.4g of indophenols dye was weighed and dissolved in 1000ml of distilled water. The indophenols solution was held in the burette. Four grams of 1% oxalic acid was weighed and dissolved in 1000ml distilled water. 20ml of the samples were added to 80ml of the oxalic acid. Two milliliters of the resulting solution was then titrated against indophenols solution until the solution turned permanently pink. The Vitamin C was then calculated as:



Mg/100 = dye equivalent × titer value × dilution; where: Dye equivalent =0.188

Dilution factor = final volume of solution/initial volume

But from every 50ml of titrated sample, 4.35 Vitamin C is contained.

Thus: 50mg = 4.35 Vitamin C.

## 3. Determination of ash

The ash represents the inorganic component (minerals) of the sample after all moisture has been removed as well as the organic material. It was determined by destructive approach based on the decomposition of all organic matter such that the mineral elements may be lost in the process, (Nwodo *et al.*, 2012).

Five grams of granular sample was weighed into porcelain crucible in duplicate. The sample was put into furnace for 4 hours at 550$^{o}$C. The furnace was then allowed to cool below

200$^{o}$C and maintained for 20 minutes. The ash crucible was removed from the furnace, placed in the desiccators to cool and weighed.

The ash content was then calculated according to the formular:

(A + B) – A = B

(A + C) - A = C therefore

% Ash = C/B x 100 where A = crucible weight, B = sample weight, C = ash weight.

### 4. Ether Extract (Fat) Determination



The method employed was the Soxhel extraction technique described by Shir Law (1967) according to Nwodo *et al*., 2012. An extraction flask was placed in an oven for about 5mins at 110$^{o}$C then cooled and weighed. A piece of filter paper was folded in such a way to hold the sample. A second filter was wrapped around, which is left open at the top like a thimble. A piece of cotton wool was placed at the top to evenly distribute the solvent as it drops on the sample during extraction. The sample packet was placed in the butt tubes of a Soxhlet extraction apparatus. Extract with petroleum ether was heated for 3 hours without interruption by gentle heating. The sample was then allowed to cool and the extraction flask dismantled. The ether was evaporated on a steam or water bath until no odour of ether remains. The sample was then cooled at room temperature. The extraction flask and its extract were re-weighed and the weight recorded. The ether extract was then calculated as:

(A + B) – A = B thus; % ether extract = B/C x 100

Where; A = flask weight, B = ether extract weight, C = sample weight.

### 5. Crude Fibre Determination

The fibre forms the bulk of roughage in food and is estimated as crude fibre. It was determined according to the method by Nwodo *et al*., 2012.

The residue from ether extract was transferred in to a digestion flask. About 200 ml of the boiling $H_2SO_4$ solution was added, and anti-foaming agent also added. The digestion flask was immediately connected with a condenser and heated. At the end of 30 minutes, the flask was removed, and filtered immediately through linen and wash with boiling water until washings were no longer acid. A quantity of NaOH solution was heated to boiling point and kept at this temperature under reflux condenser until used. The residue was then washed back into the flask with 200 ml of the boiling NaOH solution. The flask was connected with reflux condenser and boiled for exactly 30 minutes. At the end of the 30 minutes, the flask was removed and immediately filtered through the Gooch crucible. After thorough washing with boiling $H_2O$, the residue was washed with about 15ml of 95% ethanol. The crucible and contents were then dried at $110^oC$ to constant weight. The crucible and its content was cooled in a desiccator and weighed. Contents of the crucible were incinerated in muffle furnace at $550^oC$ for 30mins until the carbonaceous matter has been consumed. It was cooled in a desiccator and weighed. The loss in weight was recorded as crude fibre calculated as below:

$$\% \text{ crude fibre} = \frac{A - B}{C} \times 100$$ where A = weight of dry crucible and sample

B = weight of incinerated crucible and ash, C = sample weight.

### 7. Crude Protein Determination

The total protein was determined by the kjeldal method, (Nwodo *et al*., 2012).

Two grams of the granular sample was weighed and transfer to a 500/650ml digestion flask, 10ml of distilled water was added and a 1 digestion tablet as a catalyst was also added. 20ml of concentrated $H_2SO_4$ was added to the digestion flask. Boiling chips were added and the sample was digested till the solution becomes colourless.



The digest was then cooled and diluted with a small quantity of distilled ammonia-free water and made up to100ml. A Kjeldahl flask was then rinsed with distilled water and 10ml was pipetted out of the 100ml digest into the distillation flask and 90ml distilled water was added. 20ml of 40% NaOH were also added and a conical flask containing 10ml of boric acid solution with a few drops of mixed indicator were placed. 150ml of the ammonia on boric acid was then distilled and collected.

The solution was titrated against the standard 0.1N HCl until the first appearance of pink colour, i.e. the end-point attained. A reagent was run blank with equal volume of distilled water and the titration volume subtracted from that of sample titration volume.

The N content of the sample was calculated by the formula:

$$\% \text{ Nitrogen } = \frac{(ml\ acid \times normality\ of\ standard\ acid)}{wt\ of\ sample(g)} \times 0.014 \times 100$$

Therefore, % Crude Protein (CP) = Total Nitrogen ($N_T$) x 6.25(Protein factor)

**8. Calculation of Nitrogen-Free Extract [NFE]**

The calculation of nitrogen-free extract (NFE) was made after completing the analysis for ash, crude fibre, ether extract and crude protein according to AOAC (1984). The calculation was made by adding the percentage values on dry matter basis of these analysed contents and subtracted from 100%. The NFE was calculated as follows:

NFE (%) on dry matter basis = 100% - [%ash on dry matter basis + % crudefibre on dry matter basis + % ether extract on dry matter basis + % protein on dry matter basis].

# CHAPTER FOUR

## 4.0 RESULTS

### 4.1 TEMPERATURE

The temperatures in the solar drier ranged from 36°C to 58°C. While under the sun, they ranged from 30°C to 37°C as seen Figure 4.1.

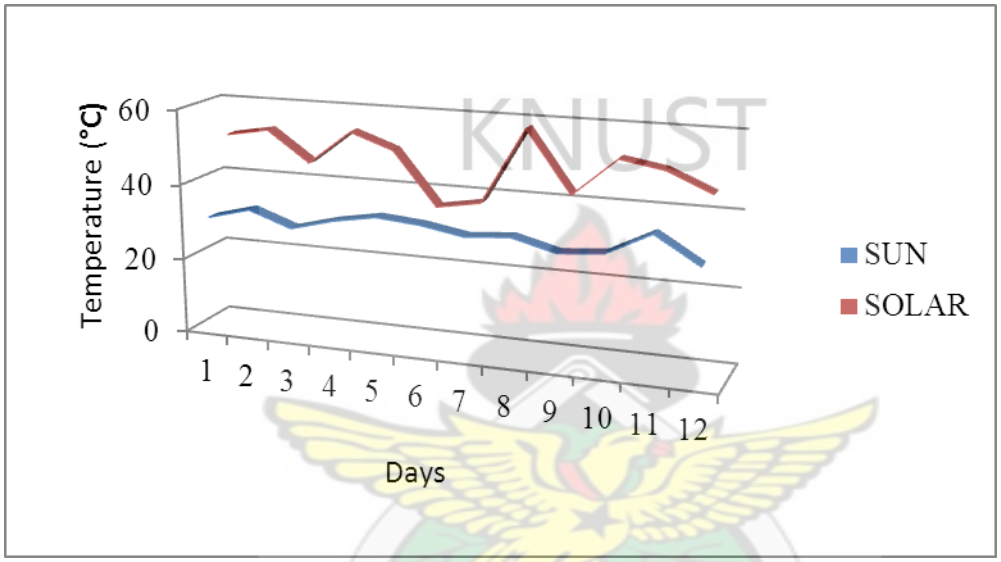


**Figure 4.1. TEMPERATURES IN DRYERS DURING DRYING OF PEPPER**

### 4.2 RELATIVE HUMIDITY

The relative humidy (RH%) in the solar drier ranged between 22% to 83%. On the other hand, the relative humidity under the ambient condition varied between 12% and 67% as presented in Figure 4.2

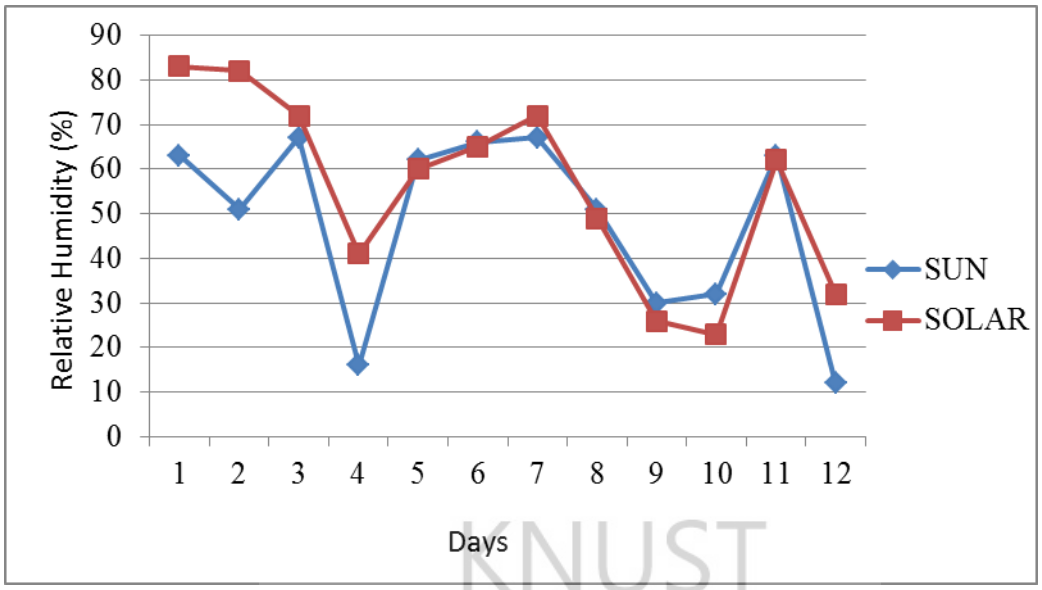


**Figure 4.2. RELATIVE HUMIDITY IN DRYERS DURING DRYING OF PEPPER**

### 4.3 CUMULATIVE WEGHT LOSS BY PEPPER SAMPLES DURING DRYING

From Figure 4.3, it was observed that pepper sample blanched in water containing oil had a steady weight loss for the first 10 days after which a sharp drop in weight occurred till the last day. Blanched in water only and not blanched however resulted in the pepper fruit losing weight gradually from day 1 till the last day.

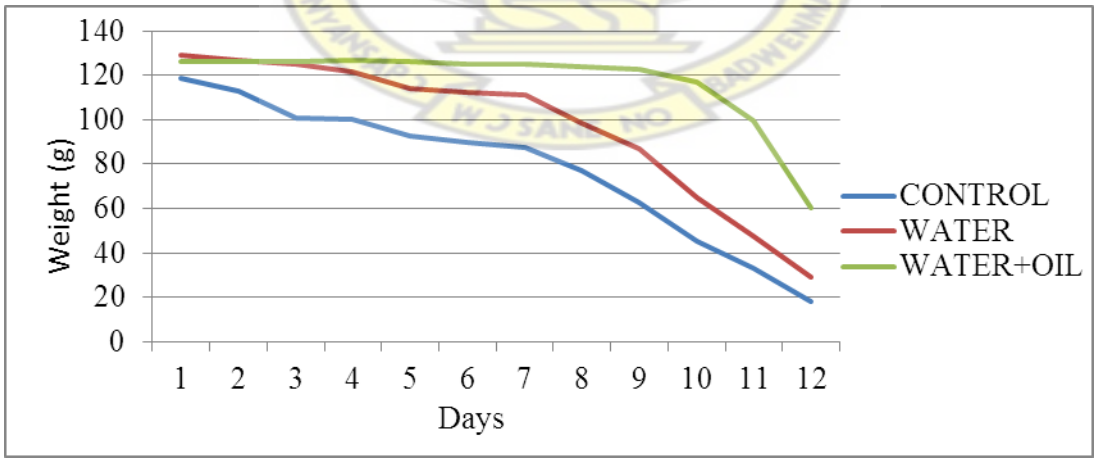


**Figure 4.3. DAILY WEIGHT LOSS BY SAMPLES FOR THE TREATMENTS**

## 4.4 MOISTURE CONTENT

Moisture or water is usually determined by the loss in weight that occurs in a sample upon drying to a constant weight. The mean moisture values obtained for the various treatments on samples are shown in Table 4.1.

**Table 4.1. Moisture Content (%) after Drying**

| TREATMENTS | SOLAR | SUN | MEAN |
|---|---|---|---|
| FRESH | | | 83.14 A |
| CONTROL | 34.55 C | 50.63 B | 42.59 B |
| WATER | 12.69 D | 12.85 D | 12.77 C |
| WATER+ OIL | 6.98 D | 6.08 D | 6.53 D |
| MEAN | 34.34 B | 38.18 A | |
| LSD | D*B=6.9078 | D=3.4539 | B=4.8846 |
| CV | 10.88 | | |

The moisture content of the fresh pepper was 83.14%. Drying using sun and solar significantly reduced the moisture content to 38.18% and 34.34% respectively. The results showed that solar drying reduced the moisture content by 41.30% whereas sun drying reduced it by 45.92%

Generally, blanching resulted in lower moisture levels compared to the Control (not blanched). However, blanching with water containing oil resulted in the least moisture content (6.53%). This represented 92.15% loss in moisture compared to the fresh sample.

On the other hand blanching in water alone reduced the moisture content of the pepper sample by 85%. As regards the control, there was only 48.77% moisture loss.

Blanching irrespective of the method of drying resulted in the lowest moisture content. However, the results showed that the sample blanched with water containing oil and dried under sun had marginally lower moisture content (6.08%). The results indicate that drying the control sample in the sun had higher moisture content (50.63%) than the rest.



## 4.5 PROTEIN DETERMINATION

**Table 4.2. Values of protein (%) of Pepper after Drying**

| TREATMENTS | SOLAR | SUN | MEAN |
|---|---|---|---|
| Water | 11.98 C | 13.73 B | 12.85 B |
| Water with oil | 11.15 DE | 10.97 E | 11.06 C |
| Control | 13.43 B | 14.37 A | 13.90 A |
| Mean | 12.00 B | 12.60 A | |
| Lsd | D*B=0.49 | D=0.24 | B=0.34 |
| CV | 2.26 | | |

The sample dried under sun had significantly higher protein content (12.60%) than that dried in solar (12.00%). The control sample recorded higher protein content (13.90%) than those blanched both in water alone (12.85%) and in water containing oil (11.06%). There were however significant difference among the results obtained.

The control sample dried under sun had the highest protein content (14.37%) which was significantly different from the rest. This was followed by the sample blanched in water alone and dried under sun (13.73%) which was not significantly different from the control sample dried in solar (13.43%). The samples blanched in water containing oil however recorded lower values of protein content for both samples dried in solar (11.15%) and under the sun (10.97%) which were not significantly different from each other.



## 4.6 VITAMIN C CONTENT

The vitamin C content found in the various samples varied with the various treatments as indicated in Table 4.3 below.

**Table 4.3 Vitamin C Content (mg/100g) of Pepper after Drying**

| TREATMENTS | SOLAR | SUN | MEAN |
|---|---|---|---|
| FRESH | | | |
| CONTROL | 4.63 AB | 5.45 AB | 4.87 AB |
| WATER | 4.07 B | 4.39 B | 5.04 AB |
| WATER+ OIL | 4.83 AB | 6.09 A | 4.23 B |
| MEAN | 4.73 A | 5.07 A | 5.45 A |
| LSD | D*B=1.5843 | D= 0.7921 | B=1.1203 |
| CV | 18.47 | | |

The Vitamin C content for the samples blanched with water only and dried under sun and in solar drier was 4.39mg/100g and 4.07mg/100g respectively. However those blanched with water containing oil showed significant differences in the Vitamin C content of samples dried under sun (6.08mg/100g) and in solar drier (4.83mg/100g). The sample blanched with water only had the mean Vitamin C content (4.23mg/100g) lower than the fresh sample. The results showed that blanching in water containing oil maintained Vitamin C level by 89mg/100g. While blanching in water alone maintained Vitamin C content by 86mg/100g.



The samples blanched in water only and dried under both sun and in solar drier do not show significant differences in the Vitamin C content. Whereas the sample blanched in water containing oil and dried under sun, recorded higher Vitamin C content (6.08mg/100g), the sample blanched in water alone and dried in solar drier recorded lower Vitamin C content (4.07mg/100g) compared to the control dried under sun, which recorded 5.45mg/100g Vitamin C content.

## 4.7 MOULD GROWTH

**Table4. 4 Mould Growth ($cfu^{-1}$) on Dried Pepper**

| TREATMENTS | SOLAR | SUN | MEAN |
|---|---|---|---|
| FRESH | | | 5.37 A |
| CONTROL | 4.28 C | 4.85 B | 4.57 B |
| WATER | 2.11 E | 4.27 C | 3.19 C |
| WATER+ OIL | 1.93 F | 3.12 D | 2.52 D |
| MEAN | 3.42 B | 4.41 A | |
| LSD | D*B=3.478E-03 | D=1.739E-03 | B=2.460E-03 |
| CV | 0.05 | | |



The pepper sample dried in solar drier had least mould growth (3.42$cfu^{-1}$) as compared to the sample dried under sun which recorded (4.41$cfu^{-1}$). Blanching had significantly reduced mould growth on the pepper sample. As can be seen in the Table 4.4, the sample blanched in water only recorded mould growth of 3.19$cfu^{-1}$; while the sample blanched in water containing oil had 2.52$cfu^{-1}$ mould growth. However, the fresh sample recorded 5.37$cfu^{-1}$, while the control had 4.57$cfu^{-1}$ mould growth.

The pepper sample blanched in water containing oil and dried in solar had less mould growth (1.93$cfu^{-1}$) as compared to those blanched in water only and dried in solar (2.11$cfu^{-1}$) drier. Whereas pepper sample blanched in water containing oil and dried under the sun had significantly lesser mould growth (3.12$cfu^{-1}$), the sample blanched in water alone and dried

in sun had relatively less mould growth (4.27cfu$^{-1}$) as compared to the control that was dried in sun (4.85cfu$^{-1}$).

## 4.8 DRY MATTER CONTENT OF PEPPER

**Table 4.5 Dry matter values (g) of pepper sample**

| **TREATMENT** | **SOLAR** | **SUN** | **MEA** |
|---|---|---|---|
| CONNTROL | 126.67 AB | 110.67 B | 118.67 B |
| WATER | 129.33 A | 129.33 A | 129.33 A |
| WATER+OIL | 118.67 AB | 130.67 A | 124.67 A |
| **MEAN** | 124.89 A | 123.56 A | |
| LSD | B*D= 17.319 | D =9.999 | B=12.246 |
| CV | 7.66 | | |

The sample blanched in water containing oil and dried under sun recorded relatively higher dry matter value (130.67g) as compared to the control dried also under sun (110.67g). Whereas the sample blanched in water alone recorded the same dry matter values for the various drying methods (129.33g), the control had 126.67g dry matter higher than the sample blanched in water containing oil (118.67g) both dried in solar.

## 4.9 ASH CONTENT OF PEPPER

**Table 4.6 Values of Ash Content (%) of pepper after drying**

| TREATMENTS | SOLAR | SUN | MEAN |
|---|---|---|---|
| Water | 16.17 A | 12.17 C | 14.17 A |
| Water with oil | 5.77 D | 6.03 D | 5.90C |
| Control | 13.87 B | 13.93 B | 13.90 A |
| Mean | 10.98 A | 10.02 B | |
| Lsd | D*B=0.49 | D=0.24 | B=0.34 |
| CV | 2.65 | | |

The sample dried in solar was significantly higher in ash content (10.98%) than the sample dried under sun (10.02%). The sample blanched in water alone had the highest value of ash content (14.17%) followed by the control which recorded (13.90%). However, the sample blanched in water containing oil had the least ash content (5.90%).

Generally the sample blanched in water alone and dried in solar recorded the highest ash value (16.17%). This was followed by the control samples (13.87%) and (13.93%) which did not show any significant difference between the drying methods, solar and sun respectively. The sample blanched in water containing oil however, had the least values of ash for sample dried in solar (5.77%) and the one dried under sun (6.03%) as indicated in Table 4.6.

## 4.10. THE FAT CONTENT OF PEPPER

**Table 4.7 Fat content (%) of Pepper after Drying**

| TREATMENTS | Solar | Sun | Mean |
|---|---|---|---|
| Water | 3.17 E | 3.17 E | 3.17 C |
| Water with oil | 12.27 B | 15.03 A | 13.65 A |
| Control | 2.87 E | 4.43 D | 3.65 B |
| Mean | 5.85 B | 6.89 A | |
| LSD | D*B=0.49 | D=0.24 | B=0.34 |
| CV 4.37 | | | |



The sample dried under sun recorded higher fat content (6.89%) as compared to the sample dried in the solar drier (5.85%).The sample blanched in water containing oil recorded the highest fat content (13.65%) among the treatments. This was followed by the control (3.65%) and the sample blanched in water alone (3.17%).

The sample blanched in water containing oil and dried under sun recorded the highest fat content (15.03%) followed by its counterpart dried in the solar drier (12.27%). However, the fresh sample dried in solar had 5.10% followed by the fresh sample dried under sun (4.93%). The control sample dried under sun recorded 4.43% as compared to 3.17% for the sample blanched in water alone and dried in either solar or sun. The control sample dried in solar had the least value of fat content (2.87%).

## 4.11. FIBRE CONTENT

**Table 4.8 Fibre values (%) of Dried Pepper**

| TREATMENT | Solar | Sun | Mean |
|---|---|---|---|
| WATER | 23.50 D | 23.85 CD | 23.67 B |
| Water with oil | 20.36 E | 20.62 E | 20.49 C |
| Control | 25.44 B | 30.45 A | 27.95 A |
| Mean | 23.35 B | 24.71 A | |
| Lsd | D*B=0.49 | D=0.24 | B=0.34 |
| CV | 1.16 | | |



The fibre content of the sample dried under sun was higher (24.71%) than the sample dried in solar (23.35%).The control sample recorded higher fibre content (27.95%) compared to samples blanched in both water alone and water containing oil. However, the sample blanched in water alone had high fibre content (23.67%) than the sample blanched in water containing oil which recorded 20.49%.

The control samples dried under sun and solar recorded highest fibre values (30.45%) and (25.44%) respectively than the rest. This was followed by samples blanched in water alone and dried in both sun and solar (23.85%) and (23.50%) respectively. The samples blanched in water containing oil and dried in both sun and solar however recorded lower fibre values (20.62%) and (20.36%) respectively.

## 4.12 DETERMINATION OF NITROGEN FREE EXTRACT

**Table 4.9. Values of Nitrogen Free Extract (%) of Dried Pepper**

| TREATMENT | Solar | Sun | Mean |
|---|---|---|---|
| Water | 32.03 C | 33.93 B | 32.98 B |
| Water with oil | 35.30 A | 33.50 B | 34.40 A |
| Control | 29.74 D | 22.47 E | 26.11 C |
| Mean | 33.20 A | 31.36 B | |
| Lsd | D*B=0.49 | D=0.24 | B=0.34 |
| CV | 0.86 | | |



The sample dried in solar was significantly higher in Nitrogen Free Extract value (33.20%) than the sample dried under sun which had 32.36% value of Nitrogen Free Extract. The sample blanched in water containing oil recorded 34.40% Nitrogen Free Extract which was significantly higher than the samples blanched in water alone and the control that had 32.98% and 26.11% Nitrogen Free Extract values respectively.

The sample blanched in water containing oil and dried in solar had Nitrogen Free Extract value (35.30%) that was significantly higher than the rest. This was followed by the samples blanched in water alone and dried under sun (33.93%) and in water containing oil also dried under sun (33.50%) that had no significant difference between them. The control sample however, recorded lower Nitrogen Free Extract values (29.74%) and (22.47%) dried in solar and under sun respectively.

## 4.13 MICROORGANISMS ASSOCIATED WITH ROT OF PEPPER

The various microorganisms associated with pepper samples under the various treatments and drying methods were as indicated in Table 4.10.

**Table 4.10 Bacteria Identified Growing on Pepper Sample**

| | SAMPLES | MICROSCOPY |
|---|---|---|
| 1. | $H_2O$ sun | Staphylococcus aureus and Bacillus species |
| 2. | $H_2O$ + oil sun | Bacillus species |
| 3. | Control sun | Bacillus species |
| 4. | $H_2O$ solar | Bacillus species |
| 5. | $H_2O$ + oil solar | Bacillus species |
| 6. | Control solar | Bacillus species |

# CHAPTER FIVE

## 5.0 DISCUSSIONS

### 5.1 MOISTURE CONTENT OF PEPPER

The results suggest that solar drying was more efficient in reducing moisture levels in Scotch Bonnet than sun drying. This could be attributed to higher temperatures in the solar drier used (46 °C) compared to the ambient temperature of 32°C averagely. Similar findings has been reported by Abugre *et al.* (2011) who reported that solar drying was more efficient than sun drying in drying *Cleome gynandra*.

The higher extent of moisture loss observed in the blanched treatments in this study can be attributed to the fact that blanching accelerates drying by distorting the cell wall of the fruits thus increasing rate of water loss from the fruits during drying. This corroborates the findings of Owusu *et al.,* (2008**)** who reported that blanching enhances drying as without blanching the sample of pepper just continued to shrink, some even turned white in colour.

The lower moisture content of the sample blanched with water containing oil could be attributed to the fact that the oil serves as a coat that does not allow the fruits to absorb water during blanching (Hassan *et al*., 2007). This does not happen in the case of blanching with water alone as the fruits absorb some water during the blanching thus increasing moisture content of the fruits. However loss of moisture of the fruits during drying occurs in the form of vapour which is not prevented by the oil. Farmers and processors can therefore adopt this technology for proper drying and to preserve pepper for storage.

Though the sample blanched in water with oil and dried in solar did not show result significantly different from the sample dried under sun, it was relatively higher (6.98%). This could be attributed to the high humidity condition in the solar (Fig.4.2) that did not allow complete drying of the sample. Thus processors of pepper can adopt blanching with water containing vegetable oil and dry under sun for better preservation.

## 5.2 VITAMIN C CONTENT OF PEPPER



The samples dried in sun recorded higher content of Vitamin C (5.07mg/100g) while samples dried under solar drier recorded less (4.73mg/100g). This could be attributed to the high temperatures in the solar drier which probably caused disintegration of Vitamin C.

The results showed that blanching in water containing oil maintained higher content of Vitamin C (5.45mg/100g) than blanching in water alone (4.23mg/100g). This could be attributed to the fact that Vitamin C is soluble in water (Nwodo *et al.,* 2012). Thus the sample blanched in water alone might have absorbed the water which dissolved the Vitamin C. However, oil coats the fruits blanched with water containing the oil which prevented water absorption by the fruits.

Whereas the sample blanched in water containing oil and dried in sun, recorded higher Vitamin C content (6.08mg/100g), the sample blanched in water alone and dried under solar drier recorded lower Vitamin C content (4.07mg/100g) compared to the control dried in sun, which recorded 5.45mg/100g Vitamin C content. The samples dried in sun recorded higher content of Vitamin C (5.07mg/100g) while samples dried under solar drier recorded less (4.73mg/100g). The high Vitamin C content of sample blanched in water containing oil and

dried in sun could be attributed to the inability of the fruits to absorb water which would have dissolved the Vitamin C during the blanching. Also drying in the sun did not have temperatures high enough to evaporate the Vitamin C.

### 5.3 MOULD GRWTH ON DRY PEPPER

The results indicate that whereas the sample dried in solar drier had 63% mould growth, the sample dried in sun recorded 82% mould growth compared to the fresh sample. Mould growth is promoted by the presence of warm moist condition on the product (Banaras *et al*., 2005). This could therefore be attributed to the high rate of drying in the solar drier which did not allow the required environment for the mould growth as compared to the slow pace of drying in the sun.

As can be seen in Table 4.4, the sample blanched in water only recorded 3.19cfu$^{-1}$ mould growth; while the sample blanched in water containing oil had 2.52cfu$^{-1}$ mould growth. However, the fresh sample recorded 5.37cfu$^{-1}$, while the control had 4.57cfu$^{-1}$ mould growth. The less percentage mould growth of the sample blanched in water containing oil could be attributed to the fact that the oil coat on the fruits prevented moisture presence on the surface. This did not encourage the mould growth as oil is not a good substrate for mould growth. On the other hand, the sample blanched in water only might have absorbed some water which allowed the presence of moisture on the fruits thus creating good atmosphere for the growth of mould. However, the fresh sample had high percentage mould growth because; it was not subjected to any heat treatment and microbial action started earlier before drying.

Whereas sample blanched in water containing oil and blanched under the sun had significantly lesser mould growth ($3.12cfu^{-1}$), the sample blanched in water alone and dried in sun had less mould growth ($4.27cfu^{-1}$) as compared to the control that is dried in sun ($4.85cfu^{-1}$). This could be attributed to the effect of the heat treatment that destroyed microorganisms on the product during blanching (Seenappa *et al.,* 1987). However, the sample blanched in water containing oil and dried in solar had least mould growth ($1.93cfu^{-1}$) as compared to the sample blanched in water alone and dried in solar ($2.11cfu^{-1}$). This could be attributed to the obvious reason that mould is a fungus that requires warm moist environment for growth which blanching in water containing oil did not allow.



## 5.4 DRY MATTER CONTENT OF PEPPER

As regard to the interaction, sun drying of the pepper sample had significantly lower dry matter content (110.67g) than the rest which were similar.

Generally, no significant differences were observed among the method of drying as well as the pre-drying treatment which suggested that they had similar effects on the dry matter content of the pepper.

## 5.5 ASH CONTENT OF PEPPER

Ash content of fruits gives indication of the amount of minerals in the food (Appiah *et al.*, 2011). According to the authors, very high levels of ash could be indicative of presence of heavy metals, known to be toxic, in foods.

The study revealed that drying using solar technology was capable of maintaining the level of ash. However, sun drying was less effective in maintaining ash content. The higher ash content of solar followed by sun dried samples may indicate higher mineral elemental composition of pepper (*Capsicum chinense*). Similar results have been reported by Matazu and Haroun (2004).

However, the outcome of this study suggests that using solar drying technology is recommended than sun when maintenance of ash content is of interest. The control, which did not go through any blanching procedure, was as good as the samples blanched in water alone in maintaining ash content of the pepper samples. On the other hand, blanching with water containing oil led to reduced levels of ash.

The significant interaction between blanching in water alone and drying using solar technology resulted in higher ash levels. In contrast, there was a significant loss in ash when the pepper samples blanched in water containing oil was dried in solar. The higher ash content of the water alone x solar interaction could be due to the pepper fruits absorbing dissolved minerals in the water compared to the control (which was not blanched). However, there could have been an antagonistic effect of oil resulting in the Water containing oil x solar inability to absorb some minerals from the water used for blanching (Hassan *et al*., 2007).

## 5.6 THE FAT CONTENT OF PEPPER

The volatile nature of fat resulted in the reduction of fat content of the sample dried in solar due to the high temperature compared to lesser temperature under the sun. Blanching in water containing oil was able to maintain high amount of fat compared to blanching in water alone. This could be attributed to fact that the oil prevented the escape of fat from the pepper sample. The control which did not go through blanching procedure still had the escape of fat during drying. Blanching in water alone reduced the fat content which could be due to the heat treatment that accelerated evaporation of the fat since there was no waxing coat as the oil.



As blanching in water containing oil might have prevented the escape of fat from the pepper sample, drying under sun also had reduced temperature which reduced the escape of fat from the sample. However, drying similar sample in the solar might have increased the escape of the fat due to high temperature.

## 5.7 FIBRE CONTNT OF PEPPER

The results from this study indicated that mineral element composition of *Capsicum chinense* vary with drying method. The higher temperature in the solar could have increase the digestibility of fibre in the pepper sample. However, it may be due to environmental, genetic factors and the method of analysis employed. Natural non-nutrients in foodstuffs are known to be destroyed by heat during processing (Matazu and Haroun, 2004). In general, the observed increases or decreases in the nutrients and non-nutrients components of dried samples may be attributable to the lost of water molecules.

Fresh fruits and vegetables provide us with bulk energy, mineral and vitamins. Bulk was provided by the indigestible fibre recorded higher in the control sample. This study thus revealed that blanching led to reduction in the fibre content of pepper. The drastic reduction in fibre content of the sample blanched in water containing oil could mean that digestibility of fibre had increased as a result of the presence of oil which could increase temperature. This is similar to the report by Matazu and Haroun (2004) who reported that non-nutrients in foodstuffs are known to be decreased by heat upon processing.



The interactions did followed the trend that the samples dried under sun recorded higher fibre content as compared to their counterparts dried in solar irrespective of the treatment. However, the control samples recorded the highest fibre content followed by samples blanched in water alone and the samples blanched in water containing oil recorded the least value for fibre content of pepper.

According to this study, sun drying in general proved to maintain high fibre content thus can be considered the best method of drying pepper for maximum fibre yield. However, blanching tend to reduce the fibre content though blanching in water alone maintained a bit higher amount of fibre content than blanching in water containing oil.

**5.8 PROTEIN CONTENT OF PEPPER**

The 0.6% drop in protein of the sample dried in solar drier could be attributed to the higher temperature in the solar which denatures the protein. The control sample which did not go through blanching procedure maintained higher amount of protein as compared to those

samples blanched. This was in accordance to the fact that heat denatures protein and as blanching involved heat treatment it might have caused denaturing of the protein content in the pepper fruits.

The significant higher protein content of the control sample dried under sun could be attributed to the fact that the sample did not undergo any heat treatment thus maintaining the protein content of the pepper fruits. However, those samples blanched in either water alone or water containing oil could have their protein denatured resulting in the low values of protein content of the pepper fruits. Though the sample blanched in water alone and dried under sun maintained reasonable amount of protein (13.73%), it was an indication that when blanching of pepper was necessary, then the fruits have to be dried under sun for maximum protein content.



### 5.9 THE NITROGEN FREE EXTRACT CONTENT OF PEPPER

Solar drying was able to maintain high amount of Nitrogen Free Extract of the pepper sample than sun drying. This could be attributed to the many mineral escaping from the pepper sample dried under the sun which did not occur as much as in solar.

Blanching in water containing oil maintained high amount of Nitrogen Free Extract than blanching in water alone. This could be attributed to the oil preventing the elements from evaporating. The control however, which did not undergo heat treatment maintained higher amount of Nitrogen Free Extract in the sample compared to the sample blanched in water

alone. This could be attributed to the heat denaturing some minerals during the blanching process.

The significant higher Nitrogen Free Extract content of the sample blanched in water containing oil and dried in solar could be attributed to the presence of oil and the fast drying in solar. The sample blanched in water alone and dried under sun however became next in the sense that sun drying was relatively lower in temperature compared to the solar thus did not evaporate the Nitrogen Free Extract.



As far as technology was concerned blanching in water containing oil was best in maintaining Nitrogen Free Extract content. Drying in solar was appropriate when the pepper sample was blanched in water containing oil. Whereas drying under the sun proved better when the fruits were blanched in water alone.

### 5.10 MICROORGANISMS ASSOCIATED WITH ROT OF PEPPER

Such microorganisms as staphylococcus aureus and bacillus species were the pathogens found associated with rot of pepper during drying. Those organisms cause diseases of various degrees. Care should therefore be taken to minimize if not avoid their presence in food products. Blanching and drying could have minimized the growth of microorganisms on pepper samples as only the two species were found in association with rot of pepper.

# CHAPTER SIX

## CONCLUSION AND RECOMMENDATIONS

### 6.1 CONCLUSION

Pepper is mostly preserved through drying. The difficulty lies when the variety is the pulpy type which is not only rotting but also takes long time to dry. From the study, it is observed that blanching actually enhanced drying of the pepper and improved its durability.



Blanching with water containing oil increased the rate of drying which can be concluded as the ideal pre-drying method for pepper (*Capsicum chinense*). The study has also shown that solar drying should be the method of choice when drying pepper. It is also known that solar drying results in the production of products that are more hygienic than sun drying. Farmers and processors using this technology would not have to be apprehensive about poor weather and could therefore adopt this technology.

The results showed that blanching in water containing oil maintained Vitamin C level by 89%. Thus showing the need to include vegetale oil to blanching of pepper as far as maintenance of Vitamin C was concerned. As far as maintaining ash levels in the pepper samples were concerned, solar drying of pepper blanched in water alone is the method of choice. However, when the technologies are concerned, not blanching and blanching in water were equally acceptable than blanching with oil. As far as the drying method was concerned, solar drying is the method of choice.

This study thus revealed that blanching in water containing oil and drying under sun should be the method of choice as far as maintenance of fat was concerned. The results from this study indicated that mineral element composition of *Capsicum chinense* vary with drying method. The higher temperature in the solar could have increase the digestibility of fibre in the pepper sample. However, it may be due to environmental, genetic factors and the method of analysis employed. Natural non-nutrients in foodstuffs are known to be destroyed by heat during processing (Matazu and Haroun, 2004). In general, the observed increases or decreases in the nutrients and non-nutrients components of dried samples may be attributable to the lost of water molecules.



According to this study, sun drying in general proved to maintain high fibre content thus can be considered the best method of drying pepper for maximum fibre yield. However, blanching tend to reduce the fibre content though blanching in water alone maintained a bit higher amount of fibre content than blanching in water containing oil.

Protein content of food had been necessary to maintain, but when preservation of pepper fruits were concerned then blanching in water alone and drying under the sun was appropriate.ras drying under the sun proved better when the fruits were blanched

As far as technology was concerned blanching in water containing oil was best in maintaining Nitrogen free extract content. Drying in solar was appropriate when the pepper sample was blanched in water containing oil. Whereas drying under the sun proved better when the fruits were blanched in water alone.

## 6.2 RECOMMENDATIONS

In order to dry hot pepper well and maintain its quality for all times in Northern Ghana, the following recommendations are made.

Educational programmes should be put in place by the Government, NGOs and other stakeholders to increase people awareness of the nutritional value of pepper in our diet.

Farmers' organizations should be formed at the local level to facilitate the education on the preparation, application and benefits of the right technology of drying pepper for storage.

More research work should be conducted on proper preservation for that matter storage of pepper to enable its availability for considerable period of the year.

## REFERENCES


1. Andrews (1984): Peppers the Domesticated Capsicums, University of Texas press, Austin.
2. Banaras M., P. W. Bosland and N.K. Lownds (2005); Effects of Harvest Time and Growth Conditions on Storage and Post-Storage Quality of Fresh Pepper (*Capsicum annuum* L).
3. Boatright, S. R., and C. McKissick (2004): Georgia Farm Gate Value Report, AR 05-01. University of Georgia College of Agricultural and Environmental Sciences, Centre for Agribusiness and Economic Development.
4. Boudreaux *et al.,* (1987): Commercial Vegetable Production Recommendations.
5. Dupriez (1989): African Gardens and Orchards, pp.267-268.
6. Greenleaf (1986): Pepper breeding, pp. 67-134.
7. Hassan S. W., R. A. Umar, H. M. Maishanu, I. K. Matazu, U. Z. Faruk and A. A. Sani (2007); Effects of Dying Method on the Nutrient and non-nutrient Compositions of Leaves of Gynandropsis gynandra (Capparaceae). Asian Journal of biochemistry.
8. Hassan S. W., R. A. Umar, I. K. Matazu, H. M. Maishanu, A. Y. Abbas and A. A. Sani (2007); Nutrition and non-nutritional Composition of Leaves of *Leptadania hastata* (Asclipiadaceae). Asian Journal of biochemistry.

   http://www.nass.usda.gov/ga/
9. Koslewicz. Second Edition (1979): Preparation and storage of fruits and vegetables.
10. Lipton (1979): Pepper Production Guide, University of Florida Coop. EXT.

11. Lucier, G., and C. Plummer (2003); Vegetables and Melons Outlook. Electronic Outlook Report from the Economic Research Service, USDA, VGS-298, August 21.
12. Nwodo S. Chinedu and C. Obinna Nwinyi (2012); Proximate analysis of sphenostylis stenocarpa and Voadzeia subterranean consumed in South-Eastern Nigeria.
13. Robert Owusu (2008); Postharvest Programme CSIR-Savanna Agricultural Research Institute Annual Report pp. 31.
14. Russell L. and R.L. MacDowell (1989); Vitamins and Animal Nutrition Comparative Aspects of Human Nutrition.
15. Seenappa M., L. W. Stobbs and A. G. Kempton (1980); Aspergillus Colonization of Indian Red Pepper During Storage.
16. Sims (1976): Growing peppers in California University, California.
17. Tindall (1983): Vegetables in the tropics.
18. ToDD P. H., Bensinger M. G. and Bifty T. (1977); Gas-liquid Chromatography Journal of Food Science.
19. Villa (1987): Horticultural classification grown in the US.
20. Villalon (1981): Breeding peppers to resist virus diseases.
21. Wolfe K. and E.G. Fonsah. Wholesales and Distributions Outlook for Fruit and Vegetables Produced in Georgia. GFVGA News Vol. 7, No. 4, Fall.

# APENDIX

## 1 anovo tables

Student Edition of Statistix 9.0 4/11/2012, 8:48:55 AM

**Analysis of Variance Table for cumulative weight loss day1**



| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| REP | 2 | 179.11 | 89.56 | | |
| DRYING | 1 | 8.00 | 8.00 | 0.20 | 0.6651 |
| TRET | 2 | 5789.78 | 2894.89 | 71.97 | 0.0000 |
| DRYING*TRET | 2 | 300.00 | 150.00 | 3.73 | 0.0617 |
| Error | 10 | 402.22 | 40.22 | | |
| Total | 17 | 6679.11 | | | |

Grand Mean 35.778 CV 17.73

**Analysis of Variance Table for cumulative weight loss day2**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| REP | 2 | 652.4 | 326.22 | | |
| DRYING | 1 | 10.9 | 10.89 | 0.11 | 0.7493 |

| | | | | | |
|---|---|---|---|---|---|
| TRET | 2 | 14669.8 | 7334.89 | 72.70 | 0.0000 |
| DRYING*TRET | 2 | 565.8 | 282.89 | 2.80 | 0.1080 |
| Error | 10 | 1008.9 | 100.89 | | |
| Total | 17 | 16907.8 | | | |

Grand Mean 60.111 CV 16.71

**Analysis of Variance Table for cumulative weight loss day3**



| **Source** | **DF** | **SS** | **MS** | **F** | **P** |
|---|---|---|---|---|---|
| REP | 2 | 225.3 | 112.67 | | |
| DRYING | 1 | 64.2 | 64.22 | 1.07 | 0.3257 |
| TRET | 2 | 16576.0 | 8288.00 | 137.83 | 0.0000 |
| DRYING*TRET | 2 | 519.1 | 259.56 | 4.32 | 0.0445 |
| Error | 10 | 601.3 | 60.13 | | |
| Total | 17 | 17986.0 | | | |

Grand Mean 75.667 CV 10.25

**Analysis of Variance Table for cumulative weight loss day4**

| **Source** | **DF** | **SS** | **MS** | **F** | **P** |
|---|---|---|---|---|---|
| REP | 2 | 67.4 | 33.72 | | |

DRYING 1 84.5 84.50 1.48 0.2521

TRET 2 11000.1 5500.06 96.17 0.0000

DRYING*TRET 2 602.3 301.17 5.27 0.0274

Error 10 571.9 57.19

Total 17 12326.3

Grand Mean 90.611 CV 8.35



**Analysis of Variance Table for cumulative weight loss day5**

| **Source** | **DF** | **SS** | **MS** | **F** | **P** |
|---|---|---|---|---|---|
| REP | 2 | 21.78 | 10.89 | | |
| DRYING | 1 | 128.00 | 128.00 | 1.77 | 0.2134 |
| TRET | 2 | 6459.11 | 3229.56 | 44.55 | 0.0000 |
| DRYING*TRET | 2 | 585.33 | 292.67 | 4.04 | 0.0518 |
| Error | 10 | 724.89 | 72.49 | | |
| Total | 17 | 7919.11 | | | |

Grand Mean 99.778 CV 8.53

**Analysis of Variance Table for cumulative weight loss day6**

| **Source** | **DF** | **SS** | **MS** | **F** | **P** |
|---|---|---|---|---|---|

REP 2 52.00 26.00

DRYING 1 320.89 320.89 5.53 0.0405

TRET 2 4432.00 2216.00 38.21 0.0000

DRYING*TRET 2 759.11 379.56 6.54 0.0152

Error 10 580.00 58.00

Total 17 6144.00

Grand Mean 108.00 CV 7.05



**Analysis of Variance Table for cumulative weight loss day7**

| **Source** | **DF** | **SS** | **MS** | **F** | **P** |
|---|---|---|---|---|---|
| REP | 2 | 72.44 | 36.22 | | |
| DRYING | 1 | 320.89 | 320.89 | 5.71 | 0.0380 |
| TRET | 2 | 3909.78 | 1954.89 | 34.77 | 0.0000 |
| DRYING*TRET | 2 | 776.44 | 388.22 | 6.91 | 0.0131 |
| Error | 10 | 562.22 | 56.22 | | |
| Total | 17 | 5641.78 | | | |

Grand Mean 109.11 CV 6.87

**Analysis of Variance Table for cumulative weight loss day8**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| REP | 2 | 125.78 | 62.89 | | |
| DRYING | 1 | 256.89 | 256.89 | 4.53 | 0.0593 |
| TRET | 2 | 3420.44 | 1710.22 | 30.13 | 0.0001 |
| DRYING*TRET | 2 | 727.11 | 363.56 | 6.41 | 0.0162 |
| Error | 10 | 567.56 | 56.76 | | |
| Total | 17 | 5097.78 | | | |



Grand Mean 110.89 CV 6.79

**Analysis of Variance Table for cumulative weight loss day9**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| REP | 2 | 128.44 | 64.22 | | |
| DRYING | 1 | 242.00 | 242.00 | 3.68 | 0.0842 |
| TRET | 2 | 2325.78 | 1162.89 | 17.67 | 0.0005 |
| DRYING*TRET | 2 | 585.33 | 292.67 | 4.45 | 0.0415 |
| Error | 10 | 658.22 | 65.82 | | |
| Total | 17 | 3939.78 | | | |

Grand Mean 116.11 CV 6.99

Student Edition of Statistix 9.0 4/11/2012, 8:50:43 AM

**Analysis of Variance Table for cumulative weight loss day10**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| REP | 2 | 109.78 | 54.89 | | |
| DRYING | 1 | 18.00 | 18.00 | 0.21 | 0.6563 |
| TRET | 2 | 2439.11 | 1219.56 | 14.25 | 0.0012 |
| DRYING*TRET | 2 | 256.00 | 128.00 | 1.50 | 0.2701 |
| Error | 10 | 855.56 | 85.56 | | |
| Total | 17 | 3678.44 | | | |

Grand Mean 117.44 CV 7.88

**Analysis of Variance Table for cumulative weight loss day11**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| REP | 2 | 283.11 | 141.556 | | |
| DRYING | 1 | 64.22 | 64.222 | 0.82 | 0.3874 |
| TRET | 2 | 748.44 | 374.222 | 4.76 | 0.0353 |
| DRYING*TRET | 2 | 481.78 | 240.889 | 3.06 | 0.0916 |
| Error | 10 | 786.22 | 78.622 | | |
| Total | 17 | 2363.78 | | | |

Grand Mean 122.11 CV 7.26

**Analysis of Variance Table for cumulative weight loss day12**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| REP | 2 | 292.00 | 146.000 | | |
| DRYING | 1 | 32.00 | 32.000 | 0.40 | 0.5416 |
| TRET | 2 | 345.33 | 172.667 | 2.15 | 0.1667 |
| DRYING*TRET | 2 | 465.33 | 232.667 | 2.90 | 0.1013 |
| Error | 10 | 801.33 | 80.133 | | |
| Total | 17 | 1936.00 | | | |

Grand Mean 124.67 CV 7.18

Student Edition of Statistix 9.0 5/10/2012, 2:49:32 PM

**Completely Randomized AOV for drying temperature day1**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| DRYING | 1 | 560.667 | 560.667 | 480.57 | 0.0000 |
| Error | 4 | 4.667 | 1.167 | | |
| Total | 5 | 565.333 | | | |

Grand Mean 41.333 CV 2.61

**Completely Randomized AOV for drying temperature day2**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| DRYING | 1 | 504.167 | 504.167 | 756.25 | 0.0000 |
| Error | 4 | 2.667 | 0.667 | | |
| Total | 5 | 506.833 | | | |

Grand Mean 43.833 CV 1.86



**Completely Randomized AOV for drying temperature day3**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| DRYING | 1 | 0.00000 | 0.00000 | 0.00 | 1.0000 |
| Error | 4 | 4.00000 | 1.00000 | | |
| Total | 5 | 4.00000 | | | |

Grand Mean 30.000 CV 3.33

**Completely Randomized AOV for drying temperature day4**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|

DRYING 1 620.167 620.167 930.25 0.0000

Error 4 2.667 0.667

Total 5 622.833

Grand Mean 43.833 CV 1.86

**Completely Randomized AOV for drying temperature day5**



| **Source** | **DF** | **SS** | **MS** | **F** | **P** |
|---|---|---|---|---|---|
| DRYING | 1 | 160.167 | 160.167 | 96.10 | 0.0006 |
| Error | 4 | 6.667 | 1.667 | | |
| Total | 5 | 166.833 | | | |

Grand Mean 40.833 CV 3.16

**Completely Randomized AOV for drying temperature day6**

| **Source** | **DF** | **SS** | **MS** | **F** | **P** |
|---|---|---|---|---|---|
| DRYING | 1 | 24.0000 | 24.0000 | 24.00 | 0.0080 |
| Error | 4 | 4.0000 | 1.0000 | | |
| Total | 5 | 28.0000 | | | |

Grand Mean 34.000 CV 2.94

**Completely Randomized AOV for drying temperature day7**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| DRYING | 1 | 66.6667 | 66.6667 | 100.00 | 0.0006 |
| Error | 4 | 2.6667 | 0.6667 | | |
| Total | 5 | 69.3333 | | | |

Grand Mean 35.333 CV 2.31

**Completely Randomized AOV for drying temperature day8**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| DRYING | 1 | 1066.67 | 1066.67 | 914.29 | 0.0000 |
| Error | 4 | 4.67 | 1.17 | | |
| Total | 5 | 1071.33 | | | |

Grand Mean 44.667 CV 2.42

**Completely Randomized AOV for drying temperature day9**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| DRYING | 1 | 280.167 | 280.167 | 76.41 | 0.0009 |
| Error | 4 | 14.667 | 3.667 | | |
| Total | 5 | 294.833 | | | |

Grand Mean 36.833 CV 5.20



**Completely Randomized AOV for drying temperature day10**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| DRYING | 1 | 640.667 | 640.667 | 480.50 | 0.0000 |
| Error | 4 | 5.333 | 1.333 | | |
| Total | 5 | 646.000 | | | |

Grand Mean 42.000 CV 2.75

**Completely Randomized AOV for drying temperature day11**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|

DRYING 1 253.500 253.500 253.50 0.0001

Error 4 4.000 1.000

Total 5 257.500

Grand Mean 43.500 CV 2.30

**Completely Randomized AOV for drying temperature day12**



| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| DRYING | 1 | 352.667 | 352.667 | 529.00 | 0.0000 |
| Error | 4 | 2.667 | 0.667 | | |
| Total | 5 | 355.333 | | | |

Grand Mean 37.667 CV 2.17

**Completely Randomized AOV for humidity of drying envr. day1**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| DRYING | 1 | 600.000 | 600.000 | 450.00 | 0.0000 |
| Error | 4 | 5.333 | 1.333 | | |
| Total | 5 | 605.333 | | | |

Grand Mean 73.667 CV 1.57

**Completely Randomized AOV for humidity of drying envr. day2**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| DRYING | 1 | 1441.50 | 1441.50 | 1081.13 | 0.0000 |
| Error | 4 | 5.33 | 1.33 | | |
| Total | 5 | 1446.83 | | | |



Grand Mean 67.167 CV 1.72

**Completely Randomized AOV for humidity of drying envr. day3**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| DRYING | 1 | 37.5000 | 37.5000 | 28.13 | 0.0061 |
| Error | 4 | 5.3333 | 1.3333 | | |
| Total | 5 | 42.8333 | | | |

Grand Mean 70.167 CV 1.65

**Completely Randomized AOV for humidity of drying envr. day4**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| DRYING | 1 | 937.500 | 937.500 | 703.12 | 0.0000 |
| Error | 4 | 5.333 | 1.333 | | |
| Total | 5 | 942.833 | | | |

Grand Mean 29.167 CV 3.96



**Completely Randomized AOV for humidity of drying envr. day5**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| DRYING | 1 | 6.0000 | 6.00000 | 4.50 | 0.1012 |
| Error | 4 | 5.3333 | 1.33333 | | |
| Total | 5 | 11.3333 | | | |

Grand Mean 61.667 CV 1.87

**Completely Randomized AOV for humidity of drying envr. day6**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| DRYING | 1 | 1.50000 | 1.50000 | 1.13 | 0.3486 |
| Error | 4 | 5.33333 | 1.33333 | | |
| Total | 5 | 6.83333 | | | |

Grand Mean 66.167 CV 1.75



**Completely Randomized AOV for humidity of drying envr. day7**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| DRYING | 1 | 37.5000 | 37.5000 | 28.13 | 0.0061 |
| Error | 4 | 5.3333 | 1.3333 | | |
| Total | 5 | 42.8333 | | | |

Grand Mean 70.167 CV 1.65

**Completely Randomized AOV for humidity of drying envr. day8**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| DRYING | 1 | 6.0000 | 6.00000 | 4.50 | 0.1012 |
| Error | 4 | 5.3333 | 1.33333 | | |
| Total | 5 | 11.3333 | | | |

Grand Mean 50.667 CV 2.28



**Completely Randomized AOV for humidity of drying envr. day9**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| DRYING | 1 | 24.0000 | 24.0000 | 18.00 | 0.0132 |
| Error | 4 | 5.3333 | 1.3333 | | |
| Total | 5 | 29.3333 | | | |

Grand Mean 28.667 CV 4.03

**Completely Randomized AOV for humidity of drying envr. day10**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| DRYING | 1 | 121.500 | 121.500 | 91.12 | 0.0007 |
| Error | 4 | 5.333 | 1.333 | | |
| Total | 5 | 126.833 | | | |

Grand Mean 28.167 CV 4.10



**Completely Randomized AOV for humidity of drying envr. day11**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| DRYING | 1 | 1.50000 | 1.50000 | 1.13 | 0.3486 |
| Error | 4 | 5.33333 | 1.33333 | | |
| Total | 5 | 6.83333 | | | |

Grand Mean 63.167 CV 1.83

**Completely Randomized AOV for humidity of drying envr. day12**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| DRYING | 1 | 600.000 | 600.000 | 450.00 | 0.0000 |
| Error | 4 | 5.333 | 1.333 | | |
| Total | 5 | 605.333 | | | |

Grand Mean 22.667 CV 5.09



**Analysis of Variance Table for moisture content**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| REP | 2 | 10.4 | 5.19 | | |
| TRET | 3 | 22040.6 | 7346.87 | 472.17 | 0.0000 |
| DRYING | 1 | 88.2 | 88.24 | 5.67 | 0.0320 |
| TRET*DRYING | 3 | 300.5 | 100.18 | 6.44 | 0.0058 |
| Error | 14 | 217.8 | 15.56 | | |
| Total | 23 | 22657.6 | | | |

Grand Mean 36.257 CV 10.88

**Analysis of Variance Table for weight**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| REP | 2 | 261.78 | 130.889 | | |
| DRYING | 1 | 8.00 | 8.000 | 0.09 | 0.7725 |
| TRET | 2 | 343.11 | 171.556 | 1.89 | 0.2008 |
| DRYING*TRET | 2 | 592.00 | 296.000 | 3.27 | 0.0810 |
| Error | 10 | 906.22 | 90.622 | | |
| Total | 17 | 2111.11 | | | |

Grand Mean 124.22 CV 7.66

**Analysis of Variance Table for mould count**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| REP | 2 | 1.952E-05 | 9.762E-06 | | |
| TRET | 3 | 30.0593 | 10.0198 | 2539625 | 0.0000 |
| DRYING | 1 | 5.77850 | 5.77850 | 1464627 | 0.0000 |
| TRET*DRYING | 3 | 3.83697 | 1.27899 | 324175 | 0.0000 |
| Error | 14 | 5.524E-05 | 3.945E-06 | | |
| Total | 23 | 39.6748 | | | |

**Analysis of Variance Table for total viable count**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| REP | 2 | 6.591E-08 | 3.295E-08 | | |
| TRET | 3 | 6.94632 | 2.31544 | 2.9E+08 | 0.0000 |
| DRYING | 1 | 0.18271 | 0.18271 | 2.3E+07 | 0.0000 |
| TRET*DRYING | 3 | 11.7175 | 3.90583 | 4.8E+08 | 0.0000 |
| Error | 14 | 1.133E-07 | 8.099E-09 | | |
| Total | 23 | 18.8465 | | | |

Grand Mean 4.5288 CV 0.00

**Analysis of Variance Table for ASH**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| REP | 2 | 0.181 | 0.090 | | |
| DRYER | 1 | 5.510 | 5.510 | 71.05 | 0.0000 |
| SAMPLE | 3 | 313.988 | 104.663 | 1349.45 | 0.0000 |
| DRYER*SAMPLE | 3 | 18.645 | 6.215 | 80.13 | 0.0000 |
| Error | 14 | 1.086 | 0.078 | | |
| Total | 23 | 339.410 | | | |

Grand Mean 10.496 CV 2.65

**Analysis of Variance Table for FAT**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| REP | 2 | 0.181 | 0.090 | | |
| DRYER | 1 | 6.510 | 6.510 | 83.94 | 0.0000 |
| SAMPLE | 3 | 434.938 | 144.979 | 1869.27 | 0.0000 |
| DRYER*SAMPLE | 3 | 8.695 | 2.898 | 37.37 | 0.0000 |
| Error | 14 | 1.086 | 0.078 | | |
| Total | 23 | 451.410 | | | |

Grand Mean 6.3708 CV 4.37

**Analysis of Variance Table for FIBRE**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| REP | 2 | 0.181 | 0.0904 | | |
| DRYER | 1 | 11.207 | 11.2067 | 144.49 | 0.0000 |
| SAMPLE | 3 | 167.924 | 55.9748 | 721.70 | 0.0000 |
| DRYER*SAMPLE | 3 | 26.876 | 8.9586 | 115.51 | 0.0000 |
| Error | 14 | 1.086 | 0.0776 | | |
| Total | 23 | 207.274 | | | |

Grand Mean 24.031 CV 1.16

**Analysis of Variance Table for MOISTURE**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| REP | 2 | 0.1808 | 0.09042 | | |
| DRYER | 1 | 0.0104 | 0.01042 | 0.13 | 0.7195 |
| SAMPLE | 3 | 18.7879 | 6.26264 | 80.75 | 0.0000 |
| DRYER*SAMPLE | 3 | 0.1446 | 0.04819 | 0.62 | 0.6127 |
| Error | 14 | 1.0858 | 0.07756 | | |
| Total | 23 | 20.2096 | | | |

Grand Mean 14.496 CV 1.92

**Analysis of Variance Table for NFE**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| REP | 2 | 0.181 | 0.090 | | |
| DRYER | 1 | 20.112 | 20.112 | 259.31 | 0.0000 |
| SAMPLE | 3 | 326.265 | 108.755 | 1402.22 | 0.0000 |
| DRYER*SAMPLE | 3 | 69.303 | 23.101 | 297.85 | 0.0000 |
| Error | 14 | 1.086 | 0.078 | | |
| Total | 23 | 416.947 | | | |

Grand Mean 32.280 CV 0.86

**Analysis of Variance Table for PROTEIN**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| REP | 2 | 0.1808 | 0.0904 | | |
| DRYER | 1 | 2.0827 | 2.0827 | 26.85 | 0.0001 |
| SAMPLE | 3 | 31.3076 | 10.4359 | 134.55 | 0.0000 |
| DRYER*SAMPLE | 3 | 3.9420 | 1.3140 | 16.94 | 0.0001 |
| Error | 14 | 1.0858 | 0.0776 | | |
| Total | 23 | 38.5990 | | | |

Grand Mean 12.302 CV 2.26

**Analysis of Variance Table for vit**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| REP | 2 | 24.6089 | 12.3045 | | |
| TRET | 3 | 4.6425 | 1.5475 | 1.89 | 0.1776 |
| DRYING | 1 | 0.6950 | 0.6950 | 0.85 | 0.3724 |
| TRET*DRYING | 3 | 4.4275 | 1.4758 | 1.80 | 0.1928 |
| Error | 14 | 11.4584 | 0.8185 | | |
| Total | 23 | 45.8322 | | | |

Grand Mean 4.8980 CV 18.47