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Improving Household Food Security: A Comparative Analysis of Freezing and Drying on Sensory Qualities of Mushroom

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Abstract
Postharvest loss remains one of the major causes of food insecurity in developing countries such as Ghana. While mushroom is consumed by many Ghanaian households, fresh harvested mushrooms have very limited storage life. The objective of this paper is to examine the effects of freezing and drying on the keeping and sensory qualities of mushroom. In this study, mushroom samples, namely blanched frozen and unblanched frozen mushroom, were preserved by freezing and drying for a period of eight weeks. Portions of the four preserved samples as well as a control (fresh mushroom) were cooked in equal quantity, slightly seasoned with salt and lightly cooked. Thirteen panelists were involved in a consumer acceptability test in terms of color, texture, aroma, taste and overall acceptability using a nine-point hedonic scale. The results of paired sample t-tests indicated that blanched frozen sample followed by unblanched frozen and unblanched sundried were not statistically significantly different from the fresh mushroom sample in terms of sensory characteristics and overall acceptability. Color is a quality attribute, which together with aroma, taste and texture play an important role in consumer acceptability. It is recommended that fresh mushroom is preserved by blanched or unblanched freezing to avoid food spoilage and ensure food security at the household level.
Keywords: food security, preservation, freezing, drying, sensory qualities, mushroom

1.0 Introduction

Food insecurity remains one of the world's major problems. According to the Food and Agricultural Organization, approximately 795 people million are undernourished across the globe. The FAO reports noted that roughly 281 million people are undernourished in southern Asia and 23.2 percent of the population in sub-Sahara Africa suffers from hunger (FAO, 2015 & 2013). Ghana, like many developing countries, faces imminent food insecurity. It has been estimated that about 1.2 million people, representing 5 percent of Ghana's population, are food insecure. In addition, two million people are seen as vulnerable to become food insecure in Ghana (MOFA, 2015). The period of inadequate household food provision is the time between stock depletion and the next harvest (Bilinsky and Swindale, 2007). The major cause of food insecurity in Ghana and many developing countries is attributable to the greater percentage of post-harvest losses. There is limited knowledge of post-harvest management, most especially of perishable produce, resulting in high post-harvest losses of roughly 20-50 percent for fruits, vegetables, roots and tubers, and about 20-30 percent for cereals and legumes in Ghana (FFG, 2014; MoFA 2007). The need for research on small-scale preservation of highly perishable foods to prevent wastage is timely. Food security exists when all people at all times have physical and economic access to adequate, safe, acceptable and nutritious food to meet their daily requirements (FAO, 2014 & 1996). Post-harvest preservation makes local staple foods available and affordable even during off-seasons. Small-scale food preservation practices can ensure the presence of diverse nutrients, vitamins and minerals in daily diets and during lean seasons. In Ghana, mushrooms are well-known and consumed in many households. Mushroom production has increased among Ghanaian smallholder farmers as it requires just a small piece of land and provides farmers with the opportunity to increase their intake of vitamins and minerals (MoFA, 2007). While mushroom may be preserved by freezing and drying techniques, the author has not seen a comparative analysis of the effects of freezing and drying on sensory qualities of mushroom. The use of unsuitable preservation techniques may adversely affect the sensory qualities of stored vegetables and consumers would more likely accept preserved vegetables that retain most of their sensory qualities (Barrett et al., 2010). The objective of this paper was to investigate the effects of freezing and drying on the keeping and sensory qualities of mushroom.

2.0 Literature Review

2.1 Household food security

The major cause of food insecurity in Ghana is attributable to the greater percentage of post-harvest losses. There is limited knowledge in post-harvest management, particularly of perishable produce, resulting in high post-harvest losses of about 20-50 percent for fruits, vegetables, roots and tubers, and roughly 20-30 percent for cereals and legumes (MoFA 2007; Nyanteng & Assuming-Bempong, 2003). Fundamentally, food security is defined as having access by all people at all times to the food needed for a healthy life. Household food insecurity affects a wide cross-section of the population in both rural and urban areas. The concept of food security covers four key dimensions, including food availability, accessibility, utilization and stability. FAO (2014 & 1996) indicated that

one of the key determining factors of food security depends on the availability of food and its constituents. All people should have access to food physically and economically. Access to food may be determined by income ability of households and individuals. Beyond economic affordability, physical access to food is enhanced by availability of infrastructure. Utilization is a measure of a population's ability to obtain sufficient nutritional intake and absorption during a given period (Huck & Youkhana, 2008). Food handling, preparation and storage influences food utilization. Food stability emphasizes having mechanisms in place for assuring availability, access and usage, which is likely to change with risks to reduce food and nutrition insecurity. Thus, food security can be achieved by reducing post-harvest losses, and improving storage and distribution systems through capacity building of relevant stakeholders.

2.2 Mushrooms

Mushroom, an edible fungus, is the most prized commodity among vegetables owing to its high nutritive value, characteristic aroma and taste. The most common varieties of mushroom consumed include button mushroom, oyster mushroom and paddy straw mushroom. Many consumers have developed a great taste for it owing to its enormous benefits, including nutritional and medicinal values. Mushroom on the average contains about 19-35 percent high-quality protein with all the amino acids as well as most commonly occurring non-essential amino acids and amides required for robust human health (Kuyper, Van Dijk & Onguene, 2002; Oei, 1996). Mushroom is even richer in vitamins than certain vegetables. The vitamins present in mushroom include thiamine (vitamin B1), riboflavin (vitamin B2), niacin, biotine and ascorbic acid (vitamin C) (Quimo, Chang & Royse, 1990; Chang et al, 1978). Mushroom contains a significant amount of most essential minerals, such as phosphorus, sodium and potassium, and lesser amounts of calcium. The fat content in mushroom in terms of dry weight is in the range of 1-8 percent with an average of 4 percent. Unsaturated fatty acids make up at least 72 percent of the total fat content, and this is mainly because of the presence of linocleic acid. The high content of linocleic acids present in mushroom is one of the reasons why mushroom is considered a healthy food (Kuyper, Van Dijk & Onguene, 2002; Oei, 1996). It is also known to have medicinal values and certain varieties of mushrooms can inhibit growth of cancerous tumors.

2.3 Food preservation

Food preservation is the science dealing with the process of prevention of decay or spoilage of food, thus allowing it to be stored in a fit condition for future use. It is a process by which any food may be retained over a period of time without being contaminated by pathogenic organisms or chemicals and/or losing optimum qualities of color, texture, aroma, taste and nutritive value. Owing to inadequate post-harvest handling and processing facilities, post-harvest losses caused by spoilage are very high. Food preservation is known to prevent the growth of microorganisms and provide adequate conditions for food to be kept for any length of time (Srivastava & Kumar, 2002; Verma & Joshi, 2000 & Frazier, 1988). In many developing countries, there is a great post-harvest loss of cereals, tuber, fruits and vegetables. Food preservation increases seasonal availability of many foods and food processing can also enhance nutritional and food security. Further, food preservation helps to increase the shelf-life of foods and thus increases supply, and many perishable foods can be preserved for a long time. Food preservation retains the quality of food in terms of color, texture, flavor and nutritional value Food preservation includes a variety of techniques that allow food to be kept for extended periods of time without losing nutritional quality and avoiding the growth of unwanted microorganisms. The techniques of food preservation are aimed at prevention of contamination of food from damaging agents as well as the delay or prevention of growth of microorganisms in the food. Srivastava and Kumar (2002), Verma and Joshi (2000) and Frazier (1988) have all maintained that all food preservation methods are based on the general principle of an environment which inhibits the growth of spoilage microorganisms. Food is preserved by killing spoilage microorganisms and storing the food under conditions where further infection is impossible or by creating an environment which slows down or stops the growth of spoilage microorganisms. The general methods of food preservation are classified to include heat treatment, chemical preservation, drying and freezing (Srivastava & Kumar, 2002; Verma & Joshi, 2000 & Frazier, 1988).

2.3.1 Heat treatment (blanching)

Heat treatment involves application of higher temperatures to food above the thermal death point of a germ, and by doing so, the germs are destroyed and the food is preserved (Sethi, Deka & Meena, 2005; Desrosier & Desrosier, 1987). Blanching is a type of heat treatment whereby food products are subjected to high temperatures for a few minutes in order to inactivate enzyme systems. Blanching is a mild pre-cooking operation which involves the application of boiling water or steam for a short time. It is not a sole method of food preservation but is applied as a pretreatment, which is normally carried out between the preparation of raw material and later preservation. Blanching is used to destroy enzyme activity in fruits and vegetables prior to processing and it helps to reduce bacterial load on vegetables by 90 percent. This aids in preventing undesirable changes in sensory characteristics and nutritional properties that take place during storage. Blanching vegetables prior to canning, freezing or drying

assists in the removal of soil, insects and microorganisms, and destroys or slows the action of enzymes. It ensures the green color and prevents discoloring (Sethi, Deka & Meena, 2005; Desrosier & Desrosier, 1987).

2.3.2 Drying

Drying of foods is a widely applied process for increasing shelf-life and making food available during off-seasons, adding value by changing the phase structure of the native material and maintaining nutritional value. Microorganisms require moisture in order to grow and reproduce. Preservation by dehydration reduces the water content of food below a certain critical value, which discourages growth of microorganisms. Removal of water from food will also transfer water out of bacterial cells and multiplication ceases (Sethi, Deka & Meena, 2005; Desrosier & Desrosier, 1987). Horticultural crops contain enough water to permit their spoilage by the activity of microorganisms and enzymes. The purpose of dehydration is to lower water activity to a level at which deterioration of food quality takes place at a rate slow enough to allow long-term storage. Drying or dehydration reduces the amount of available moisture for microbial activities and thereby becomes shelf-stable and preservable for quite a long period. The low water content slows the rate of respiration, enzymatic action and overall deterioration rate that makes products less susceptible to decay and much easier and less expensive to store and transport. While all horticultural produce can be dried, not all commodities are converted into high-quality and good-tasting dried products. Food is dried in the sun or by air currents and artificially heated until the moisture content of food is reduced to an amount that will inhibit the growth of microorganisms. The actual percentage of moisture is variable but is typically under 30 percent. Sethi, Deka and Meena (2005) and Desrosier and Desrosier (1987) also asserted that vitamin C (ascorbic acid) retention is very sensitive to light, oxygen and moisture levels. Fat-soluble vitamins, like vitamin B (carotene), tend to be reduced by up to 25 percent during the air-drying process. However, other vitamins are more stable. It is concluded that the retention of vitamins is at the best-attainable levels unless the drying process occurs with a shorter drying time.

2.3.3 Freezing

Preservation by freezing is an excellent way to preserve fresh fruits and vegetables at the commercial and domestic levels. Most foods retain their natural color, flavor and texture better than when other methods of food preservation are used (Srivastava & Kumar, 2002; Verma & Joshi, 2000; Frazier, 1988). Freezing preserves the storage life of foods by slowing down enzymatic reactions and the growth of microorganisms. The preservation of food by freezing is based on the principle that below -18^{0}C (0°F), microorganisms do not multiply and below 0^{0}C, biochemical reactions are progressively suppressed and that the lower the temperature, the slower the deteriorative reaction. Freezing ensures the elimination of liquid water as the necessary medium for microorganism activities. The frozen food is held below the freezing point where most of the water is turned into ice. Thus, the growth of microorganisms is suppressed at low temperatures and become inactive at approximately -18ºC while enzymes, which cause chemical spoilage and consequent loss of quality, are largely inactivated below -18ºC (0°F). However, the main quality-damaging effect of freezing is on food texture and this is based on the formation of ice crystals within food structure. When water freezes, it expands in volume and the size of individual crystals related to the freezing rate has a profound effect on texture characteristics. Sethi, Deka and Meena (2005) along with Desrosier and Desrosier (1987) also reported that the rate at which foods become frozen is important and that the faster the freezing rate, the smaller the ice crystals will be and the less the structural damage. Vegetables with high moisture content do not freeze well because cellulose (in plant cell walls) tends to be broken down by enzymes regardless of the rate of freezing, making the vegetables soft. Therefore, for such food items, blanching to destroy enzyme activity is required prior to freezing. Transforming food into a frozen state quickly facilitates the size of the ice crystals becoming small. Less damage to cell walls of foods will take place and the final texture will be better. Textural changes owing to freezing are not as apparent in products that are cooked before eating because cooking also softens cell walls. The use of domestic freezers to store food at about 18ºC can be employed to ensure high quality and long storage life.

3.0 Methodology

3.1 Materials and Method

This study was carried out to determine the effects of freezing and drying on the keeping and sensory qualities of mushroom. Fresh harvested oyster mushroom was obtained from a cropping house. It was washed, stalks removed and divided into four (4) batches of 0.25 kg each. Two batches were blanched in boiling water and the remaining two batches left unbalanced. One batch of the blanched mushrooms and one batch of the unbalanced mushroom samples were preserved in a domestic deep freezer for a period of eight (8) weeks. The remaining two batches of the blanched and unbalanced mushroom sample were sundried and put in moisture resistant polythene bags and then stored on the shelf for a period of eight (8) weeks. Portions of each of the four preserved samples (blanched frozen, unblanched frozen, blanched sundried and unblanched sundried) as well as a control (fresh mushroom) were slightly seasoned with salt and lightly cooked. Equal portions of the fresh steamed mushroom sample were placed alongside uncooked fresh samples on a plate labeled A. Equal portions of each of the other four steamed mushroom samples were placed alongside uncooked samples on plates that were labeled separately as B, C, D and

E. They were also supplemented with boiled rice for assessment of overall acceptability. A preference test was performed by a 13-member panel with experience in sensory evaluation of food. The panelists were provided with spoons for tasting and a palate cleanser (sparkling water) in between tasting to avoid transfer of sensory qualities. The panelists were asked to rate their preferences and acceptability of the sample mushroom in terms of appearance, color, aroma, taste and texture of each of the preserved samples against the sensory qualities of sample "A" using a nine-point hedonic scale ranging from like extremely (9) to dislike extremely (1). A nine-point hedonic scale is the most commonly used scale by industry and researchers for testing consumer preferences and acceptability of foods. The scale is a balanced bipolar scale around neutral at the center with four positive and four negative categories representing various degrees of effects arranged successively to offer a single continuum of likes and dislikes. The scale continuum allows subjects to respond accordingly and researchers to compute the mean values of responses, thereby being able to employ parametric statistics, such as analysis of variance and t-tests (Lim, 2011).

4.0 Results and Discussion

Vegetables have attributes that do influence consumers' choice of given specific vegetables. A given vegetable is acceptable to consumers if it has an attractive appearance and color, acceptable aroma and taste as well as appropriate texture (Barrett et al., 2010). Barrett et al. (2010) noted that inappropriate preservation techniques may adversely affect the sensory qualities of stored vegetables and that consumers would more likely desire and accept preserved vegetables that retain most of their sensory qualities. In this study, it was hypothesized that there was no significant difference in sensory quality of fresh and preserved mushroom samples. A paired sample t-test was conducted to evaluate the effect of different preservation techniques (freezing and drying) on the sensory qualities (color, aroma, taste and texture) of preserved mushroom samples. A paired sampled t-test is appropriate when a researcher has two related observations per subject and wants to determine if the means on the normally distributed variables differ significantly (Pallant, 2007). Histograms drawn with normal distribution curves over them for the distributions of the various treatment variables have shown fairly normal distributions.

4.1 Evaluation of color/appearance in fresh mushroom and preserved mushroom samples

The results indicated that there was a non-statistically significant difference in color/appearance of fresh mushroom and preserved mushroom samples, blanched frozen, unblanched frozen and unblanched sundried, and mean differences were .000, .538 and .769, respectively, with 95% confidence (Table 1). Given that consumers would more readily prefer preserved mushroom sample with little differences in color/appearance to that of fresh samples, all preserved mushroom samples except the blanched dried were appreciated by the panelists with respect to color/appearance. However, blanched frozen samples emerged as the most acceptable color and then followed by unblanched frozen and unblanched sundried. The blanched sundried samples were the least accepted sample as their color was significantly different from the fresh mushroom sample (P= .00, Eta= .63). The significant difference in color might be because of the drying effect that caused changes via physical or chemical reactions. Freezing, however, promotes little physical or chemical changes and blanching inactivates oxidative enzymes.

Table 1: Comparison of color/appearance in fresh mushroom sample to preserved mushroom samples

Sample (mushroom)	N	Mean	SD	Paired Sample T-Test					
								95% CI	
				Mean difference	t-score	Sig(2 tailed	Eta	Lower	Upper
Fresh	13	7.760	.832	.000	.000	1.000		-.652	.652
Blanched Frozen	13	7.769	.725						
Fresh	13	7.769	.832	.538	1.849	.089		-.096	1.173
Unblanched frozen	13	7.230	.832						
Fresh	13	7.769	.832	2.923	4.392	.001	.631	1.453	4.392
Blanched sundried	13	4.846	2.230						
Fresh	13	7.769	.832	.769	1.848	.147		-.310	1.848
Unblanched sundried	13	7.000	1.290						

4.2 Evaluation of aroma in fresh mushroom and preserved mushroom samples

Table 2 shows the results of the analysis of aroma. The paired sample t-test analysis showed there to be non-significant differences in the aroma of the three preserved and fresh mushroom samples. The mean scores of the unbalanced (7.000) followed by blanched frozen (6.682) were rated to be closer in terms of aroma to that of the fresh (7.384) samples. The blanched and unblanched sundried samples were statistically significantly different from the fresh mushroom sample (P=.00, Eta= .85) and (P=.01, Eta= .58) respectively. This observation could be attributed to heating effects of blanching and drying.

Table 2: Comparison of aroma in fresh mushroom sample to preserved mushroom samples

Sample (mushroom)	N	Mean	SD	Paired Sample T-Test					
								95% CI	
				Mean difference	t-score	Sig(2 tailed	Eta	Lower	Upper
Fresh	13	7.384	1.121	.692	1.737	.108		-.176	1.561
Blanched Frozen	13	7.692	1.377						
Fresh	13	7.384	1.121	.385	1.443	.175		-.196	.965
Unblanched frozen	13	7.000	.867						
Fresh	13	7.384	1.121	2.846	8.011	.000	.853	2.072	3.620
Blanched sundried	13	4.539	1.8.8						
Fresh	13	7.384	1.121	1.769	3.179	.008	.478	.557	2.982
Unblanched sundried	13	5.615	1.805						

4.3 Evaluation of taste in fresh mushroom and preserved mushroom samples

Taste is a sensation characteristic stimulated by chemical compounds. A number of these chemicals can be lost by thermal destruction of heating. In Table 3, the mean score for the taste of each preserved mushroom sample is presented. The blanched frozen mushroom samples had the least mean difference followed by the unbalanced frozen sample with mean scores of 7.2, and 5.5 respectively. These mean scores showed there was no significant difference in taste between the fresh samples and preserved mushroom samples. The p values indicating non-significant differences suggested the two preserved samples were close to the fresh mushroom in terms of taste and were therefore enjoyed by the panelists, except the blanched and unblanched sundried samples. The blanched and unblanched sundried samples were statistically significantly different from the fresh mushroom sample in terms of taste (P= .00, Eta=.78) and (P= .01, Eta=.49) respectively. It could be concluded that blanching or drying influenced the taste of the treated samples with undesirable taste sensation chemicals.

Table 3: Comparison of taste in fresh mushroom sample to preserved mushroom samples

Sample (mushroom)	N	Mean	SD	Paired Sample T-Test					
								95% CI	
				Mean difference	t-score	Sig(2 tailed	Eta	Lower	Upper
Fresh	13	7.769	1.092	.538	1.620	.131		-.185	1.262
Blanched Frozen	13	7.231	1.013						
Fresh	13	7.769	1.092	.846	2.513	.027		.112	1.580
Unblanched frozen	13	6.923	.862						
Fresh	13	7.769	1.092	3.538	6.175	.000	.776	2.290	4.787
Blanched sundried	13	4.231	2.088						
Fresh	13	7.769	1.092	2.077	3.483	.007	.485	.671	3.483
Unblanched sundried	13	5.692	1.797						

4.4 Evaluation of texture in fresh mushroom and preserved mushroom samples

Table 4 is a summary of the results of the evaluation of the texture of the mushroom samples. Compared to the fresh mushroom samples, blanched frozen samples were those with the most acceptable texture (soft firm) with a non-statistically significantly mean value that was different from that of the fresh samples. This was followed by unblanched frozen. These observations could be attributed to the fact that during fast freezing, tiny ice crystals are formed within the intercellular spaces and because they have little time to grow, they do not distort the cellular structure. The blanched and unbleached sundried samples had the poor undesirable texture quality along with being statistically significantly different from the fresh mushroom sample (P= .00, Eta=.83) and (P= .01, Eta=.47). Consumers have expectations for the texture of fresh vegetables. Undesirable texture of a given vegetable can turn consumers off (Barrett et al., 2010). The combined action of blanching and drying might have had an undesirable effect on the blanched dried sample.

Table 4: Comparison of texture in fresh mushroom sample to preserved mushroom samples

Sample (mushroom)	N	Mean	SD	Paired Sample T-Test					
								95% CI	
				Mean difference	t-score	Sig(2 tailed	Eta	Lower	Upper
Fresh	13	7.308	.1.316	.000	.000	1.000		-.653	.653
Blanched Frozen	13	7.308	.751						
Fresh	13	7.308	1.316	.769	1.745	.106		-.191	1.730
Unblanched frozen	13	6.539	.776						
Fresh	13	7.308	1.316	2.308	6.653	.000	.831	1.552	3.063
Blanched sundried	13	5.000	1.155						
Fresh	13	7.308	1.316	1.846	3.148	.009	.465	.544	3.148
Unblanched sundried	13	5.462	1.391						

4.5 Evaluation of overall acceptability of fresh mushroom and preserved mushroom samples

The ultimate consumer preference for a given vegetable is a combined consideration of the sensory qualities in terms of appearance, color, aroma, taste and texture. With respect to overall acceptability, the blanched frozen sample had a mean score of 7.077 followed by unblanched frozen with 7.000 with a mean score. These overall acceptability mean values were non-statistically significantly from that of the fresh sample with a mean score of 7.692 (Table 5). The unblanched and blanched unblanched sundried samples were the least accepted. Their overall acceptability mean values were statistically significantly different from that of the fresh sample (P= .00, Eta=.84) and (P= .01, Eta=.52) respectively.

Table 5: Comparison of overall acceptability in fresh mushroom sample to preserved mushroom samples

Sample (mushroom)	N	Mean	SD	Paired Sample T-Test					
								95% CI	
				Mean difference	t-score	Sig(2 tailed	Eta	Lower	Upper
Fresh	13	7.692	1.182	.615	1.979	.071		-.062	1.293
Blanched Frozen	13	7.077	.862						
Fresh	13	7.692	1.182	.692	2.420	.032		-.069	1.316
Unblanched frozen	13	7.000	.707						
Fresh	13	7.692	1.182	4.385	7.663	.000	.842	3.138	5.631
Blanched sundried	13	3.308	2.529						
Fresh	13	7.692	1.182	2.231	3.422	.005	.515	.810	3.651
Unblanched sundried	13	5.462	1.664						

5.0 Conclusion and Recommendation

Small-scale preservation of fruits and vegetables, such as mushroom preservation at the household level, is important to improving food security as food wastage prevents households from obtaining the food needed for adequate diets. Food preservation methods, such as freezing, blanching and drying, can retain the essential sensory qualities of mushroom and are efficient means of preserving perishable product. With fresh mushroom being the reference sample, the findings of this study indicated that blanched frozen samples followed by unblanched frozen sample were non-statistically significantly different from the fresh mushroom sample in terms of sensory characteristics and overall acceptability. The unblanched and blanched unblanched sundried samples were the least accepted by the panelists. They were statistically significantly different from the fresh mushroom sample in terms of sensory characteristics and overall acceptability. Color is a quality attribute, which, together with aroma, taste and texture, plays an important role in consumer acceptability. It is recommended that blanched or unblanched freezing are utilized to preserve fresh mushroom at the household level as these preservation techniques retain most of the sensory qualities of the fresh mushroom.

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