PROCESS DEVELOPMENT OF DEHYDRATED SCALLOP

Oleh:

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Summary

INTRODUCTION

Scallop is the most valuable marine bivalve mollusc. There are over 350 species of scallops found through out the world in the family *Pectinidae*. Many of these are found in tropical waters, and some of the more abundant species have significant commercial fisheries associated with their distribution. The majority of current world scallop production comes from three species; the Japanese scallop *(Pecten yessoensis)*, the Sea scallop (*Placopecten magellanicus*), and the King scallop *(Pecten maximus)* (Swann, 1989). The American Calico scallop *(Aequipecten gibbus)* and various european species are also important (Dre, 1991).

In Japan, consumers eat the whole scallop, just like eating the whole clams, mussels or oysters. In Europe, the roes and adductor muscles are eaten, with the roes particularly important on the largest scallops. In the United States and Canada, only the adductor muscle is commonly eated, however many seafood stores now provide wwhole, steamed and roe-on scallops.

Scallops do not posses an ability to close their shells tighly. This means that they do not posses an effective barrier against dehydration after harvesting. For this reason, they must be processed as soon as they are harvested. Raw scallop adductor muscle commonly known as the "eye" can be eaten as "sashimi" and "sushi". Fresh and frozen muscle of scallops are used in the above products (Yamanaka, 1989). It can also be used as material in smoked, dried and canned product. Since scallops have only limited shelf life at refrigeration temperatures, various methodes of extending the shelf life have been considered. Several experiments to extend the self life of scallops were conducted such as packaging of scallops with sorbat, chilling and freezing of scallops, and packaging in CO_2 (Statham and Branner, 1987; Fletcher et al., 1988). The other studies dealing with scallop processing were canning and smoking (Tanikawa, 1985). However, the information available on drying or dehydration of scallops is rather scarce.

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Dried scallops are luxurious product available in many Chinatown supermarkets in Canada and U.S. and only certain countries such as China and Japan have the drying technology for this product. In the Orient, sun drying is the most popular method of scallop dehydration, however the detail technology seems to be trade secrets. Zaitsev et al. (1969) explained that scallops can be dried either by the sun or mechanical dryer. Drying the muscle alone produces the best quality product; on the other hand, drying the whole scallop produces a darker colored of finish product which is less valuable in the market than the lighter colored adductor muscle.

In this study, various combinations of blanching and steaming time, brining and drying time were conducted to determine the most desirable method and conditions for drying of scallops using a pilot plant air dryer to the moisture content, water activity (aw), color, texture and shape.

LITERATURE REVIEW

2.1. Anatomy and Adductor Meat Count

The adductor muscle is the scallop "meat" (it is different with oysters and mussels that the word "meat" refers to everything inside the shell, not just to the adductor muscle). The adductor muscle of scallop comprises between 5 and 20 percent of the live weight of the animal, depending on the species. The meat is cylindrical, usually white or cream, sometimes a little brown or pink, composed of numerous tubular fibers running parallel from top to the bottom of the muscle. It is sometimes called the "quick". There is also a piece of harder tissue called the "catch" or "sweet meat", more like a soft gristle and consisting of smooth fibers, on one side of the muscle. The construction of the muscle, with its tubular fibers, is important because it affects the callop meat's ability to absorb and lose water during processing and storage (Dore, 1991; Swan, 1989).

Shuked scallops (adductor muscles) are graded and sold based on the number of adductor meats per sales unit. This system of piece count grading is common in seafood marketing, and is of particular importance in marketing scallops and shrimp.

Meat count, or "count" is defened as the number of adductor meats in a pound (Swan, 1989). The most common count gradaes for scallops are as follows:

- 10 - 20 count (45 g to 23 g individual weight)
- 20 - 30 count (23 g to 15 g)
- 30 - 40 count (15 g to 11 g)
- 40 - 60 count (11 g to 8 g)
- 60 - 80 count (8 g to 5 g)

2.2 Chemical Composition of Scallops

There has been some experiments mentioning that the amount of moisture, protein, fat, glycogen and ash varied widely among species, location and date of harvest of scallop. The sensory quality and cold storage stability also appear to be different among species. Those variabilities influence the taste of scallops. Miller et al (1982) found that the taste of Calico scallops is sweeter than that of Sea scallops, but it is similar to Bay scallops.

According to Zaitsev at al (1969) in general, the flesh of scallop contains 75 to 87% moisture, 0.5 to 1.2% oil, 10 to 19% proteins, 1,3 to 2.9% ash, and 0.8 to 3.4% glycogen. The flesh of adductor muscle contains less oil and ash, and more protein and glycogen than that of the mantle. The scallop flesh also contains vitamins B12, riboflavin, thiamin, and it is rich in calcium and phosphorous. It also contains various trace elements (iron, copper, manganese, zinc, iodine, cobalt and arsenic).

Table 1. Nutrient Compostion of Scallops (in 100 g)*

	Sea Scallops	Bay, Cape or Long Island	Calico Scallop
Calories (K cal)	87	80	84
Carbohydrate (g)	2.6	2.9	2.4
Protein (g)	16.2	14.8	16.1
Total Fat (g)	0.81 (0.2-1.0)	0.6 (0.3-1.5)	0.6 (0.2-1.0)
Fatty Acids:			
-sat'd (g)	0.10	0.09	0.09
-mono (g)	0.06	0.07	0.05
-poly (g)	0.24	0.22	0.21
-omega-3 (g)	0.18	0.13	0.13
Cholesterol (mg)	36	-	-

*Sourece: Nettletton (1985)

2.3. Fatty Acids

Most of the fatty acids in scallops are polyunsaturated, and there is only a small amount of saturated fatty acids. The principle fatty acids found in Hinnites (the purple hinge rock), are palmitoleic 16:1 (13-16%); linoleic 18:2 (13-16%; linolenic 18:3 (10-16%); 20:1 (12-18%) and 20:5 (19-25). Lesser amount of oleic 18:1 (5-7%); erucic 22:1 (3-6%) and 22:unknown (3-5%) were present. The trace amount of saturated fatty acids are myristic 14:0; palmitic 16:0; 17:0; and eicosanoic 20:0. The percent polyunsaturated fatty acids ranged from 52 to 57%. Principal polyunsaturated fatty acids were linoliec 18:2 linolenic 18:3 and 20:5 (Phleger et al., 1978).

2.4 Carbohydrates

Scallops are well known to be rich in glycogen and other carbohydrates compare with other kind of seafood. Studies in Japan mentioned that in adductor muscle there are fructose-6phosphate and glucose-6phosphyate which cause browning in canning (Nagayama and Kimura, 1979). According to Phleger et al. (1978) glycogen in the adductor muscle range from 0.4 to 3.4%. Scallops from Point Loma and Mission Bay scallop contains monosaccharides ranging from 1.047 to 1.739 micromoles per mg protein. The principal monosaccharides in freshly collecte adductor muscle of Rock scallops (Hinnites multirugosus) include glucose (0.527 to 1.339 micromoles per mg protein), glucosamine (0.145 to 0.256 micromoles per mg protein), galactosamine (0.088 to 0.198), sialic acid (0.028 to 0.086), mannose (0.003 to 0.,053) and fucose (0.004 to 0.126).

2.5 Drying

The basis for preservation by drying is removal of sufficient quantities of water to lower water activity (a_w) to a level which inhibits bacterial growth and slows chemical and enzymatic reactions. Some form of heat is usually involved, ranging from the sun in outdoor drying to the relatively severe hat of a commercial dryer (Bligh et al., 1988).

The purpose of drying of food are: to preserve a product for further storage and shipment, permit satisfactory utilization of the final product, reduce shipping cost, facilitate handling in further processing, icrease the capacity of other equipment in the process and to enhance the value and usefulness of waste or by-products (Moy, 1992).

According to Pigott and Tucker (1988) there are two fundamental and simultaneous processes occur during drying: (1) heat transfer to the evaporating liquid, and (2) mass transfer as the liquid moves towards the surface and subsequently evaporates. The factors governing the rates of these processes determine the drying rate. These factors are temperature, humidity and velocity of air in contact with the product, area of drying surfaces, atmospheric pressure or vacuum, and direction of the air movement.

There are two distinct periods of drying. The first or constant rate drying periods accours when the surface is wet and essentially all energy imparted to the sample goes to evaporate water. During this periods high airflow rates over the surface of the sample, higher air temperature, and drayer air (lower humidity remove water at a faster rate. Hence it is said that external factors (external to the sample) control the rate during this period of constant rate drying. The second or falling rater drying periods occurs when the water cannot migrate to the surface as fast as the heat is absorbed. Therefore, the rate of drying decreases and the product starts to rise in temperature. During this periods, flowing air speed and humidity are not major factors while higher temperatures, causing fish flesh temperature to rise, increase drying by causing faster capillary diffusion within the product. Water diffuses to the surface faster in leaner and thinner fish, whereas increased concentration of salt content decerases this water movement (Pigott and Tucker, 1988).

Drying methods of seafood vary among different countries and within the same country depending on the species used and the type of product disired. The process may use unsalted raw material or various salt additions giving salt concentrations in the final products ranging from less than 2% to over 20%. The raw materials are dehydrated to various degrees with moisture levels in the final product ranging from about 10% to 60%. Processing temperatures may range from less than 5 to up to 120°C and times from half and hour to several months (Opstvedt, 1988).

Scallops can be dried either by natural/sun drying or mechanical drying. Natural drying is only carried out in fine weather after sun rise. It takes three or four days in cloudy weather. With mecanical drying, the process is reduced to two or three days, since drying can be continued at night. Mecanical drying of scallops muscles is carried out at 50° to 60°C. These temperature have been choosen to avoid the pieces become denatured, impaired flavor, dark and wrinkled surfaces (Zaitsev et al., 1969). Furthermore it was mentioned that sun-dried scallop is lighter in color and has a better flavor than that mechanically dried because of the effect of ultra-violet rays, and well-dried mollusc flesh conains not more than 14 or 16 per cent of moisture.

The yield of dried flesh scallop in relation to wet weight are 3.7 to 5.2 per cent. The dried flesh of mollusc contains 9.6-17.2 per cent moisture, 1.6-6.4 per cent oil, 53.4 to 79.9 per cent protein, 3.7 to 13.1 percent ash and 9.2 to 21.6 per cent glycogen (Zaitsev et al., 1969).

2.6. Blancing, Cooking Losses And Drip Composition

Blanching in water or steam is essential for many foodstuffs to be preserved by drying primarily to control or prevent the action of enzymes and to reduce the initial concentration of microorganisms (Brenndorfer et al., 1985). Blanching involves subjecting raw commodities to boiling or near-boiling water temperatures for short periods. The principal function of blanching is to inactivate enzymes but the operation also partially cooks the tissues and renders the cell membranes more permeable to moisture transfer. During the blanching process, the time of exposure to the heating medium required for a given commodity depends upon several factors including size of piece, temperature, depth of load and blancing medium.

Blanching or cooking is sometimes used as a pre- treatment in the processing of dried seafood product, especially for shellfish. Consequently, it is pertinent to assess the effect of cooking on cooking losses. According to Miller et al. (1982), cooking losses for frozen scallops were highly variable but greatest for scallops stored 1.5 and 5 months. Frozen scallop stored for 3 and 4 months had the smallest cooking losses. The gross composition of cooking drip at all frozen storage times was similar. Of the approximate 10% solids content (range 9.6-10.9%), protein was the primary component (range 5.9-7.6%), along with fat (range 0.1-0.5%), mineral ash (range 1.5-1.8%), and carbohydrate (range 1.3-2.9%).

2.7. Nutrient Changes

Usually, whenever a food is processed, some changes in its, quality and nutritional value will take place. This is unavoidable. Because various external factors are applied to the food during processing to change it to a preservable product. The color, texture, flavor, and some nutrients will change. How much changes orloss dependens on the severity of the external factors applied.

The effect of processing on nutrient quality of seafood has previously been discussed by some researchers. According to Mujumdar (1983) degradation of nutritive value during air drying is a function of several parameters such as time, temperature of the sample and moisture content. Furthermore it was mentioned by Aurand et al. (1987) that during drying, volatile components, responsible for flavormay be volatilized and lost. Easily oxidizable material may undergo a drastic oxidation, catalyzed by the heat required for drying and produces off-flavors. Food pigments, in general, may be destroyed completely or converted in other products having undesirable colors and sugar may produce off-colored product. More specifically, loss of protein biological value and loss of vitamins are two major problems. One of great importance is the effect of the drying method on protein denaturation which will influence rehydration of a dried product. Aitken and Connell (1979) found that the temperatures at which the denaturation occurs (i.e. denaturation temperature) varies for the different fish proteins and for the same protein between different fish species, being related to the environmental temperatures in wich the fish live. Genereally speaking, about 90 percent of the protein is denaturated at abaout 60 to 65°C, the remaining 10 percent (tropomyosin) may be held at 100°C for a prolonged period of time without being denaturated.

The other important changes that results from heating is nonezymatic browning or the Maillard reaction. Certain amino acid residues of the protein interact with reducing sugars as well as with other carbonyls such as malonaldehyde and other lipid oxidation products (Pigott and Tucker, 1990). Amino acid lysine ismost frequently involved, but tryptophan, arginine, and histidine as well as sulfur- containing amino acids (more in seafood) are also at risk. The Maillard reaction occurs during both storage and heat treatment. The reaction is slow at room temperature and increase with increasing temperature. Another major environmental factor which influences the extent of browning is the water content of the system. Moisture content of 30 percent is most favorable for the reaction, and hence this reaction often occurs in dehydrated products (Pigott and Tucker, 1990). At water activities of 0.4-0.7, the browning reaction proceeds rapidly (Maillard, 1912 in Richardson and Finley, 1985).

The are several moethods to control the Maillard reaction (Eskin, 1990):

1. An increase in temperature or time of heat treatmen accelaretes the rate of these reactions. Thus lowering the temperature during processing and storage can lengthen the lag phase, that is the period needed for the formation of brwon-colored products.

2. A reduction of moisture content in solid food products by dehydration reduces the mobility of reactive components.

3. The Maillard reaction is generally favored under more alkaline condition, so that lowering the pH provides a useful method of control.

4. Gas packaging excludes oxygen by packing under an inert gas. This reduces the formation of lipid oxidation products capable on interacting with amino acids.

5. Removal or convertion of one of the reactants in the sugar amino-acid interaction which forms the basis of the chemical method.

6. Chemical inhibitor such as sulfur dioxide and sulfites, thiols, calcium salts, aspartic and glutamic acids.

Basides protein denaturation and Maillard reaction, there is another important change/reaction which influences nutrient values called lipid oxidation. Seafood lipids, with their wealth of polyunsaturated fatty acids, with up to sic double bonds, are highly susceptible to oxidative rancidity. Lipid oxidation is masimized at low a_w and high temperature. Carbonyl products of lipid oxidation can react with the four most limiting amino acids. (cystine, methionine, tryptophan, lysine) resulting in protein quality loss due to Maillard reaction (Aitken and Connell, 1979; Pigott and Tucker, 1990).

2.8. Alts

High water levels will encourage bacterial growth but their reproduction slows down as these levels decrease. When the food has been dehydrated to a level of less than 10 percent water, the bacterial growth may cease altogether. The presence of salt may encourage one type of bacterial and inhibit the growth of another, although those mainly responsible for food poisoning do not grow well in salt concentration exceeding 10 percent (Nettleton, 1985).

The use of salt is a characeristic aspect of the various dehydration methods used for preserving seafood (fish). Although salt serves to add flavor to the product, its major role is its preservative action, which involves the removal of water from the fish and transfer of salt into the fish; the combined effect makes the fles unsuitable for microbial growth (Van Arsdel et al., 1973).

Van Arsdel et al. (1973) also cited that the tranfer of salt into the the fish is dependent on many factors, including:

- the osmotic pressure (responsible for the water/salt exchange and dependent on the concentration of salt outside the fish).
- the thikness of the fles (the thicker the flesh, the longer the time required for the salting process).
- the temperature of the system (the higher the temperature, the quicker the salt uptake)
- the purity of the salt (pure salt penetrates more quickly)

– the freshness of the raw material (the fresher the fish, the slower the salt uptake)

– the fat content of the fish (the higher the fat content, the slower the salt uptake).

Besides the advantage as a preservative, salt has the disadvantage dealing with protein of fish. Strong salt solutions can denature proteins. By itself the denaturation may not be harmfull to the nutritional value of the product. However, denaturation of the proteins may make more active sites on the protein available for interaction with reducing sugars such as glucose,furctose as well as with other caronyls such as malonaldehyde and other lipid oxidation product (Pigott and Tucker, 1990).

2.9. Objective of Study

The objective of this study is to determine the most desirable methods and condition (including blancing) fordying scallops using a pilot plant air dryer.

3. METHODOLOGY

3.1 Drying Method

Individually quick frozen (IQF) shucked scallops purchased from supermarket and Chinatown were transported to the laboratory and thoroughly thawed in cold water. After-draining out the water they were blanched and steamed. The meat was blanched in 80°C of water, boiling water, 4% brine 80°C and 4% brine at boiling for 1,2,3,4 and 5 minutes, the others are steamed for 1,2,3,4 and 5 minutes after brining (soaking) in saturated brine for 10 minutes. The blanched and steamed meat was layer dried in artificial drier (pilot plant air drying) to remove sufficient quantity of water, to lower water activity (a_w) lower than 0.7, a level which inhibits bacterial growth and slows chemical and enzymatic reaction. Figure 1 illustrates the squence of operations for drying scallops.

3.2. Moisture Content

The moisture content of dried scallopwere determined by vacuum oven. About 5 gram of chopped dried scallop were weighed into an aluminium dish and dried in a vacuum oven for 16 hours at 65°C.

3.3 Texture Measurement

The texture (shear values) of dried scallops were measured by using a Kramer Shear Press, Food Texture Gauge, Model TG-4B (Food Technology Corporation, Rockville, Md.). The sample of dried scallop were measured for thickness and wight, and then placed in a shear compression cell. The cell comprised of stationary box (2.6" x 2.6" x 2.5") with a grid having 10 slots forming the bottom. Ten blades of 0.125 inch thickness were guided by a slotted cover and groves in the side of the box. The blades were driven through the bottom grid to first compress, then shear and extrude the test sample. The cell is constructed from aluminium and blades held by pins to allow lateral movement to facilitate alignment. Hardness was measured by rocording the highest reading, expressed as pounds force per gram (lb f/g).

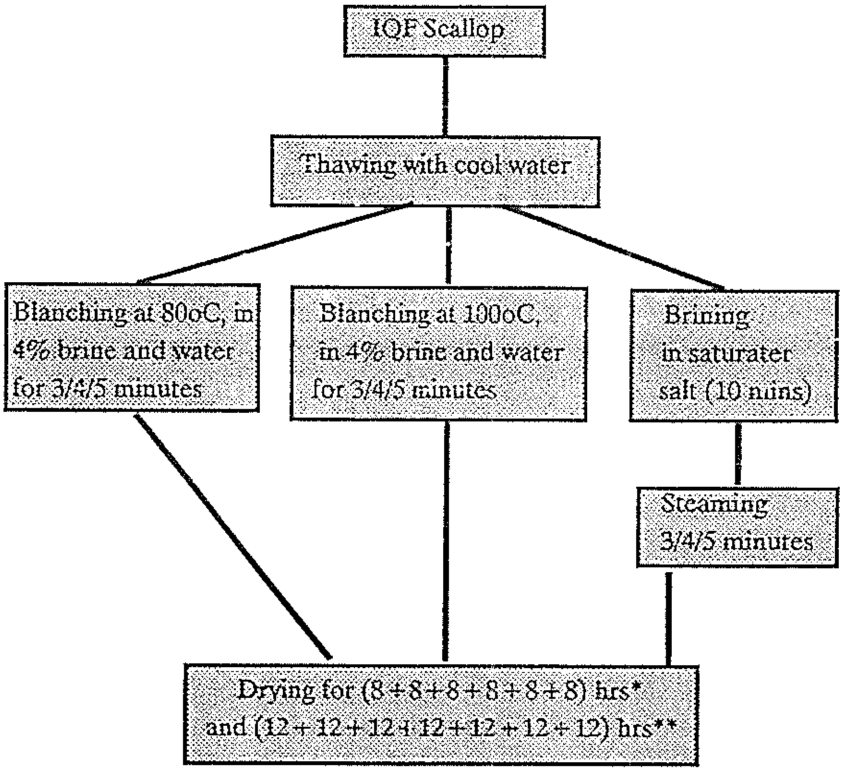

Figure 1. Sequence of Operations for Drying Scallops

Note: * Drying for 6 days, 8 hours a day
** Drying for 6 days, 12 hours a day

3.4. Color Determination

The color of samples (dried scallops) were determined by using a Hunterlab colorimeter (Model D25-PC2, Reston, Virginia). Prior to sampling, the instrument was calibrated using black and white standard plates of known L*a*b* values.

The dried scallop, placed on black plates, centered on the holding stand of the instrument and L*a*b* values were recorded. Dried scallops then turned and another set of L*a*b* reading were taken.

3.5. Water Activity

The water activities of dried scallops were determined by using DECAGON CX- 1 Water Activity System (Decagon a_w meter). Chopped dried scallops were placed in the plastic container (half full), inserted in the instrument, the instrument was then swiched on and the a_w values were recorded.

4. RESULTS AND DISCUSSION

4.1. Blanching And Weight Loss

The size of scallop adductor meats used for this study varied over a wide range of weight (9g-45g). Mainly the scallops, bought from Chinatown (product of Japan) were bigger than that from other supermarkets and the texture were also different. The raw material bought from supermarket were more tender than scallops from Chinatown.

The total weight loss during blanching and steaming was summarized in Table 2 based on fresh ice-free scallops. from this table it can be clearly seen that the longer the blanching or steaming time the greater the weight loss. This loss contains mainly water (Findlay and Stanley, 1984), meanwhile Miller et al. (1982) found that approximately 10 percent solid of cooking loss contains protein, fat, ash and carbohydrate.

Blanching is critical point in drying of scallop. It will influence the texture and hadness of the product because some changes will occur in the meat during heating. The principal function of blanching is to inactivate enzymes, but the operation also partially cooks the tissues and renders the cell membranes more permeable to moisture transfer. Findlay and Stanley (1984) in their study heated previously frozen commercial scallop to internal temperature of 25 to 80°C. They found that a linear increase in hardness of 0.033 N/g/°C (using Warner-Bratzler Shear) occuredduring heating grom 25 to 60°C; this increase was primarily a function of water loss. This was followed by a stepwise increase of 0.14 N/g/°C between 60 and 65°C which is considered to be a result of denaturation of myofibrillar proteins. Hardness continued to increase above 65°C at a rate of 0.055/N/g/°C. They also detected that scallop heated from 25 to 50°C exhibited 30 percent damaged fibers; from 55 to 65°C, damage increase from 45 to 65 percent, paralleling the increase in hardness. Above 65°C, damage reached a maximum of 70 percent. All of the above changes are critical for the final product of scallop dehydration, and it seems that those damages during blanching cause dried scallops difficult to be rehydrated.

Table 2. Total Weight Loss of Scallops during Blanching and Steaming

	Blanching at 80°C (5)	Blanching at 100°C (%)	Steaming (%)
1 minute	15.5	27.4	17.7
2 minutes	34.6	40.2	18.9
3 minutes	36.8	46.9	42.2
4 minutes	41.4	49.4	45.0
5 minutes	53.2	53.4	53.2

4.2. Drying, Moisture Content And Water Activity

The temperature range in the drier during drying operation was observed to be 25-50°C. This temperature was choosen because it is considered to be the optimum temperature that the product can withstand without serious injury/problem, and also similar to sun-drying temperature. Preliminary studies indicated that high drying temperature and high air velocity (using fan) influenced the texture of dried scallops (causing in case hardening).

The drying rate of dehydration of scallops can be seen in figure 2 also figures 3 and 4 in appendix. Drying rates were monitored by regularly weighing selected batches of scallops. From those figure it can be seen that the rates of drying for scallops blanched at 100°C were considerably greater than the average drying rates of scallops that were either steamed or blanched at 80°C. This phenomena is perhaps due to the defference of scallops permeability; in other word scallops blanched at 100°C are more permeable to moisture transfer than others.

Table 3 and 4 showed the yields of dried scallops respetively. The yields of dried scallops range from 9.8 to 17.4 percent. It can be clearly seen that the yields are much higher than that mentioned by Zaitsev et al. (1969) about 3.7 to 5.2 percent in relation to wet weight. The highest yields are the scallops which wre steamed before drying, paralleling with the moisture content which are also highest compared with others. The experimental dried scallops contain moisture ranging from 12.06 percent to 21.82 percent (Tables 5 and 6). Meanwhile according to Zaitzev et.al (1969) the dried flesh of molluscs contain 9.6 to 17.2 persent moisture.

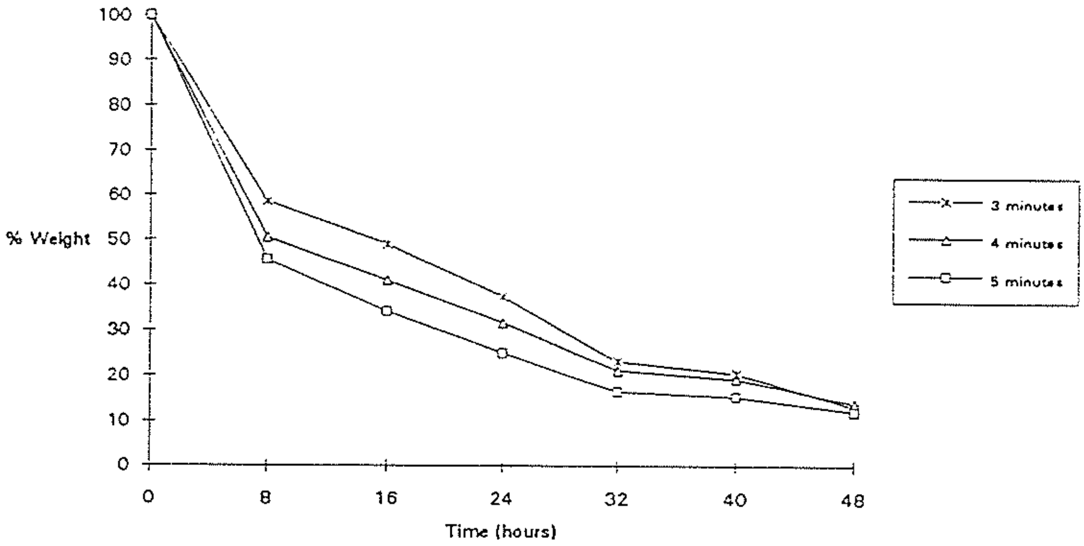

Figure 2. The drying rate curve of scallops blanched in 4% salt at 80°C, dried for (8+8+8+8+8+8) hour

Table 3. The Yields of Drieds Scallops in Relation to Wet

	Blanchging 4% salt	80°C NO	Blancing 4% salt	100°C NO	Steaming 4% salt	NO
3 minute	13.0	15.1	14.1	13.0	16.7	15.1
4 minute	13.8	13.1	12.8	13.7	14.4	13.3
5 minute	12.1	12.9	10.1	9.8	14.2	12.5

Table 4. The Yields of Drieds Scallops in Relation to Wet Weight, dried for (12 + 12 + 12 + 12 + 12 + 12) hrs

	Blanching 80°C 4% salt	NO	Blanching 100°C 4% salt	NO	Steaming 4% salt	NO
3 minutes	13.6	13.2	13.5	13.1	14.1	16.8
4 minutes	12.7	11.6	13.2	11.3	13.9	13.8
5 minutes	11.3	11.3	10.9	11.5	13.0	15.2

The average moisture content of the commercial dried scallops was 14.35 percent (for large dried scallops). and 17.42 percent (for small dried scallops). The weight of large dried scallops ranged from 7.98 to 11.5 gram and the thickness is abaout 2 cm, meanwhile the weight of small dried scallop ranged from 4.3 to 5.45 gram and the thickness is around 1.3 cm. The average of water activity is 0.58 (for large dried scallops) and 0.61 (for small dried scallops).

Tables 7 and 8 illustrate the water activity of experimental dried scallops respectively. From those tables it can be seen that all of the scallops respectively. From those tables it can be seen that all of the scallops dried for (12 + 12 + 12 + 12 + 12 + 12) hours have water activity lower than 0.7. In the contrary scallops dried for (8 + 8 + 8 + 8 + 8 + 8) hours, some of them still have water activity higher than 0.7, which will give opportunity to some micro-organisms especeally molds to grow. In some experimental trials, some molds had already grown before the complete drying processes were done. the wight and thickness of experimental dried scallops ranged from 1.57 to 6.04 gram and 0.7 to 1.74 centimeter, respectively.

In general the dried scallops containing salt had lower water activity compare with those that blanched/steamed without salt. This phenomena is perehaps due to the function of salt as humectant.

Table 5. The Moisture Content of Scallops, dried for (8 + 8 + 8 + 8 + 8 + 8) hrs

	Blancing 80oC 4% Salt	No	Blanching 100oC 4% salt	NO	Steaming 4% Salt	NO
3 minutes	17.16	21.4	19.49	13.16	21.82	20.69
4 minutes	16.16	15.89	16.87	12.99	20.64	15.86
5 minutes	15.92	14.43	14.88	12.58	14.96	14.86

Table 6. The Moisture Content of Scallops, dried for (12 + 12 + 12 + 12 + 12 + 12) hrs

	Blanching 4% salt	80°C NO	Blanching 4% salt	100°C NO	Steaming 4% salt	NO
3 minutes	14.48	13.51	18.15	16.77	21.42	20.09
4 minutes	13.69	12.06	17.93	14.45	17.09	17.19
5 minutes	13.45	12.63	14.51	13.87	14.15	13.31

Table 7. The Water of Scallops, dried for (8 + 8 + 8 + 8 + 8 + 8) hrs

	Blanching 4% salt	80°C NO	Blanching 4% salt	100°C NO	Steaming 4% salt	NO
3 minutes	0.66	0.76	0.63	0.72	0.69	0.67
4 minutes	0.68	0.76	0.68	0.70	0.66	0.68
5 minutes	0.69	0.71	0.66	0.68	0.65	0.72

Table 8. The Water of Scallops, dried for (12 + 12 + 12 + 12 + 12 + 12) hrs

	Blanching 4% salt	80°C NO	Blanching 4% salt	100°C NO	Steaming 4% salt	NO
3 minutes	0.64	0.66	0.64	0.67	0.69	0.69
4 minutes	0.61	0.65	0.64	0.67	0.63	0.67
5 minutes	0.61	0.63	0.67	0.68	0.65	0.69

4.3.Texture

Tables 9 and 10 showed the result of texture measurements of experimental dried scallops. The average breaking force of the dried scallops as measured by the Kramer Shear Perss ranges from 110 to 168 lb-f/gram. Meanwhile the average for the commercial dried scallop are 178.4 lb-f/gram for large dried scallops (ranging from 160.4 to 207.3) and 146.15 lb-f/gram for small dried scallops (ranging from 125.45 to 159.92). The products that have low breaking force usually contain some cracks. The degree of freshness of the raw material perhaps influences the breaking force of the final product. In this case the degree of freshness either the eommercial or the experimental product are unknown. The rate of freezing, the thawing method, and the temperature of cold storage/refrigerator can cause for more drip to occur due to ice crystal formation and its effect on cellular structure.

Therefore the dried scallops produced from fresh scallops and frozen scallop probably have different breaking forces.

After drying, some products contains numerous cracks, and very easy to break, which is sometimes sain to be "honeycombed". According to Van Arsdel et al. (1973) the large differences in moisture content within a single piece of material create shrinkage effects that depend upon the rate of drying. If a piece of highly shrinking material is dried so slowly that its center is never very much water than the surface, internal stresses are minimized and the material shrinks down fully onto a solid core. On the contrary, if it is dried rapidly the surface become much dried than the center and are placed under sufficient tension to give them a permanent set in nearly the original dimentions of the piece; when the interior finally dries and shrinks, the internal stresses pull the tissue apart. The dry flesh then contains nomerous cracks and holes. This phenomena also occur when the fresh scallops were not completely blanched, resulting different moisture content within a single scallop, in another word the center was very much watter (juicier) than the surfae. In this experiment the product that contains numerous cracks and holes usually come from the bigscallops blanched for three or less minutes.

Table 9. The Texture of Scallops dried for (8+8+8+8+8+8) hrs

	Blanching at 80°C		Blanching at 100°C		Steaming	
	4% salt	NO	4% salt	NO	salt	NO
3 minutes	127	126	125	117	110	132
4 minutes	111	125	145	122	121	168
5 minutes	148	142	131	147	149	161

Table 10. The Texture of Scallops, dried for (12+12+12+12+12+12) hrs

	Blanching at 80°C		Blanching at 100°C		Steaming	
	4% salt	NO	4% salt	NO	salt	NO
3 minutes	120	117	158	140	137	142
4 minutes	166	117	160	131	122	153
5 minutes	144	140	147	136	163	159

4.4. Color

Color and discoloration of many foods are important quality atributes in marketing. Although they do not neccessarily reflect nutritional, flavor, or functional values, they relate to consumer preferences based on the appearance of the product. According to Pomeranz and Meloan (1987) color characteristics of foods can result from both pigmented and originally non pigmented raw material.

The broad area of color in foods may be divided into two general sub-topics:

1. Addition of approved synthetic colors to achieve a desired appearence and
2. Determination of natural pigments (Francis 1963 in Pomeranz and Meloan, 1987).

Natural pigments in foods are determined as an index of economic value (i.e., in grading) or to control color in processing and storage and color is one of the more prominent visible characteristics of raw and cured product.

The color of dried scallops is an important factor as an index of economic value. According to Zaitsev et al (1969) the dried scallop with lighter color is more valuable than the darker one. The most obvious and irreversible changes that accompany the drying of scallop was the color change called browning. Table 11 showed the color measurement of final dried scallops. During dyrying, the color of scallops change gradually from white/cream to yellow and brown. These changes can peraps be regarded as a non-enzymatic browning, prominent as Maillard reaction. This reaction occur when carbonyl groups (for example, in some of the reducing sugar) or other lipid oxidation products (aldehyde and ketone) react with amino groups, as in amino acids or proteins. As was previously cited, scallops are rich in sugar such as glucose-6-phosphate, fructose- 6 phospate, glucosamine, and galactosamine and also rich in highly unsaturated fatty acids wich are higly susceptible to oxidative rancidity. Martin et al (1982) also mentioned that glucose and ribose are the chief free sugars identified in fish and shellfish. In addition to free sugars, a variety of sugar phosphates have been found in the muscle of fish and shellfish. Major phosphorylated sugars identified as browning reactants in fish and shellfish muscle include ribose-5 P, glucose-6 P, and furctose-6 P (Flick and Martin, 1992). Those substances can reats with amino groups from amino acids or protein.

From some experimental trials using different raw material (from Supermarket and Chinatown), and within sample having the same treatment, it was clearly seen that the final dried products originated from different supermarket are somewhat different in color. Some products had lighter color than the others. This phenomena possibly due to the differences of degree of freshness (quality) of raw material and the species of scallops. Hiltz and Dyer (1973) found that thawed scallops originally from prerigorfrozen and postrigorfrozen contain different levels of metabolites such as hexose monophosphates (glucose-6P, Fructose-6P, and glucose-1-P), hypoxanthine (Hx), octopine, nucleotides and their degradation products. As was previously discussed, those sugars are the precursor of browning reaction. If the original amount of sugar are different it will produce different color for the products. Volatile bases such as ammonia, trimethylamine, dimethylamine are ussualy present in scallops and would have lowered the quality of dried scallops by contributing to browning reaction (Flick and Martin, 1992). Thus if the degree of reshness of raw scallops is different it may produce different color.

In general the scallops blanched at 100°C has lighter color than others which are indicated by the higher L* values when compared with the others (Table 11). This is due to incomplete inactivation of the enzymes in scallops with shorter blanching times Nagayama and Kimura (1979) found that the formation of glucose-6-phosphate was suppressed by enzyme incativation when the temperature of scallops attained to 70°C or higher during the boil-sucking process. They also found that the concentration of enzymes phosphoglucomutase and glucosephosphate isomerase in scallops blanched at 80°C were higher than that in scallops blanched at higher temperature (90°C). These enzymes are important in glycogen degradation. they also found that concentration of glucose-6phosphate in water used for blanching at 90°C was higher (130 u mol) hthan that in 80°C (65 u mol). Therefore the remained glucose-6phosphate in the meat blanched at 80°C was higher than that in 90°C. The color measurement may also be influenced by the raw material. Because some material have white color on the surface (freezburn) that could not be eliminated either by blanching nor drying. Therefore some dried product still contain white color on the surface.

Table 11. The Color Measurement of Experimental Dried Scallop, dried for (12+12+12+12+12+12) hrs

	Blanching at 80°C		Blancing at 100°C		Steaming	
	brine	water	brien	water	brine	water
3 min L*	36.3	34,1	40.115	48.7	39.6	42.7
a*	2.3	2.0	-2.5	3.7	-1.9	3.5
b*	15.74	13.75	15.6	17.1	14.4	11.9
4 min L*	35.25	34	42.4	44.6	37.8	42.7
a*	4.38	4.02	-2.4	0.8	-1.7	3.6
b*	14.63	13.4	12.9	13.2	11.6	16.3
5 min L*	36.5	36.3	41.8	38.9	37.4	38.7
a*	0.4	-0.6	-1.6	-1.8	-1.4	0.96
b*	13.7	13.8	14.4	14.5	11.6	12.4

Table 12. The Moisture Content, Water Activity, Texture and Color of Commercial Dried Scallop.

	Large Scallop	Small Scallop
Moisturecontent (%)	14.35	17.42
Water Activity	0.58	0.61
Texture (lb-f/gram)	178.4	146.15
Color L*	35.4	42.5
a*	1.1	-0.96
b*	17.9	12.7

5. SUMMARY AND CONCLUSION

Study was made to determine the most diserable methods and conditions, including blanching and steamig, for drying scallops using a pilot plant air dryer. The scallops were blanced in water and 4% brine at 80°C and 100° for 3/4/5 minutes, meanwhile the others were soaked in saturated brine (10 minutes) and steamed for 3/4/5 minutes. Then they were dried in a pilot plant dryer at 25-50°C for (8+8+8+8+8+8) hours and (12+12+12+12+12+12) hours. The analyses were for moisture, a_w, texture and color.

Based on the results of this study, dehydration of scallops require attention on the blanching temperature and time, the drying time, the species and perhaps the degree of freshness of raw material.

The shape and texture of scallops blanched over 3 minutes are very close to the commercially dried scallops and there are no cracks; on the contrary the scallops blanched for less than 3 minutes has many cracks after drying.

A study of the effect of drying time on water activity showed that the water activity of scallops dried for 6 days (12 hours a day) are lower than 0.7, meanwhile those that dried for 6 days (8 hours a day) some of them still have water activity higher than 0.7 and in some experimental trials, some molds had already grown before the complete drying processes were done. Sodium chloride (salt) as humectant used in blanching decrease the water activity.

During drying the color of scallops change gradually from white/cream to yellow and brown due to the no-enzymatic browning. In general, the scallops blanched at 100°C had lighter color than the others, however in general they are similar to the commercial dried product. The following is an overview or comparison between commercially dried scallop and experimentally dried scallops (Table 13).

Table 13. An overview commercially and experimentally dried scallop

	Commercial	Experimental
Weight (gram)	4.3-11.5	1.57-6.04
Thisckness (cm)	1.3-2.0	0.7-1.74
Moisture content (%)	14.11-18.42	12.58-21.82
Water Activity (a_w)	0.58-0.64	0.61-0.76
Color L* a* b*	35.4-42.5 -0.96-1.1 12.7-17.9	34.0-48.7 -0.6-4.38 11.6-17.1

Further work may be needed toeliminate the differences and to provide the best product among different species by using the same species and the same degree of frehness in the same trial. Other studies may include sensory comparisons of the commerecial product and the experimental product using more sphisticated experimental design.

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