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The study of shrimp drying by greenhouse drying combined with low humidity air

Natthawat Wisaiprom[a *], Nat Kasayapanand[a], Naris Pratinthong[a], Roongrojana Songprakorp[a], Sirichai Thepa[a], Sindoem Deeto[b]

[a]*Solar Energy in Agriculture Laboratory, Division of Energy Technology, School of Energy, Environment and Materials, King Mongkut's University of Technology Thonburi, 126 Prach u-tid Road, Bangkok, 10140, Thailand*

[b]*Faculty of Sciences and Agricultural Technology, Rajamangala University of Technology Lanna, Tak Campus, 41 Phahonyothin Road, Tak, 63000, Thailand*

Abstract

The objective of this research was to examine the qualities of shrimps dried by a process of solar drying combined with low humidity air (45 %Rh, 30 ^oC). In the study, the shrimps were dried in solar dryer (greenhouse dryer) during daytime followed by drying in climate controlled system, which is coordinated with air conditioner, during the night. The low air temperature and relative humidity drying system consists of the humidity control unit (ultrasonic), air-conditioner, temperature and relative humidity sensors, heating coil, and microcontroller unit. For low-temperature drying process, the climate control system controls the compressor in the air conditioner by turning the compressor on-off to control the temperature and relative humidity in the chamber. The dehumidification process controls the surface temperature of the evaporator coil close to the dew point temperature, making water vapor in the air condensed to be water drops. The physical properties of the products such as color, hardness, temperature and moisture content were evaluated. The result shows that the greenhouse combined with low humidity air drying takes 16 hr drying time to reduce the 380% initial moisture content to the 14% (d.b) final moisture content of the shrimp. The average temperature and relative humidity in the solar dryer were 45 °C and 47% Rh during a daytime. At night, the low-temperature and low–Rh drying system kept the temperature in a range of 28-30°C and relative humidity at 40-45 %Rh for drying shrimp. The average temperature and relative humidity for drying were at 29.25°C, 42.58% Rh. The qualities of color was 34.51 ± 5.03^b. Compared with other drying methods, there was no significant difference ($p>0.05$) in this quantity. However, the highest shading value of 152.45 Newton was found by drying using the greenhouse drying combined with low moisture drying.

Keywords: Solar drying, Low humidity air, Shrimp

1. Introduction

Shrimp is one of the main marine products with strongest worldwide trade interests. Shrimp production has significantly increased in recent years, and it now ranked as the fishery product with the greatest economic impact in the world. Fresh and frozen shrimp are the main presentations under which this crustacean is marketed. However, some products as dried salted shrimp are manufactured in several countries to be used in the preparation of traditional foods. Dried salted shrimp is prepared by boiling raw shrimp in brine, dried under direct sunlight for 3–5 days, and packaged in plastic bags for bulk storage [1]. This process brings about several changes in structural and biochemical components that affect the overall sensory profile of the product [2]

Thailand is considered one of the world's major seafood exporters. In 2016, Thai food industry is valued USD 27.4 billion. The growth rate of the previous year was 4.0 .The export of food was expected to expand well, including shrimp, chicken and pineapple canned [3]. Seafood processing is a major export product of Thailand. Reportedly, the export value of processed seafood of Thailand in 2019 includes 69,422 tons of shrimp and 68,535 tons of canned tuna [4], which can generate great revenue for the country. Seafood processing can generate incomes for the country as

* Manuscript received June 7, 2018; revised September 5, 2018.
Corresponding author. Tel.: +66 956402537 ; E-mail address: natthawat.wis@mail.kmutt.ac.th
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well [5]. In particular, dried shrimp is a highly nutritious food product, especially protein, which is an important food ingredient [6]. Those products, currently have quality issues due to that the production processes are difficult and not meet the standards. Thailand is located in the equatorial region, which is heated by solar energy continuously throughout the year. The intensity of solar radiation has an average of 5 kWh/m^2 [7].

Therefore the use of solar energy has been continuously developed. Preserving food by traditional sun drying, such as drying meat, fish, vegetables and fruits, will have dust, germ, microbial and flies. Moreover, solar drying is limited only in daytime [8]. The drying process is to vaporize the water in the dried material factors of this process depend on the temperature, humidity and wind speed drying. The drying process requires high heat because it shortens the drying time, but the heat in the air temperature must be appropriate to the material properties. Commonly, every heat dryers have operated in the range 35-70 C°, such as, fluidized bed dryer [9], vacuum heat pump dryer [10]

The use of high heat to evaporate moisture from the agricultural products also affect in a loss of fresh, color, texture and vitamins [11]. Drying of agricultural products in Thailand is normally done by open sun drying. Although solar drying offers is a cheap method, but often results in inferior quality due to its dependence on weather conditions and risks to the attack of insect, pests, fungi, microorganisms and dust. However, solar dryer who uses solar energy was energy resource has two main weaknesses. It is the drying dis- continuously and is dependent on the weather conditions and the location. In during night time, when the solar is off, ambient temperature decreases, the relative humidity increases. Which in some cases, the red chili dried object will reabsorb the moisture. These will the longer drying time and the worse the fungal emergence in the product [12]. Notice that the fungus does not occur during drying, but is usually found after drying, by relative humidity in the air to accumulate in shrimp during storage. Under these conditions, low temperature drying combined with solar drying was used for drying shrimp. It has been reported that the relative humidity level in the air can affect the growth of fungi, Anthony V. Arundel was found that the fungi in the air grew well at relative humidity higher than 60% [13] as shown in Fig. 1

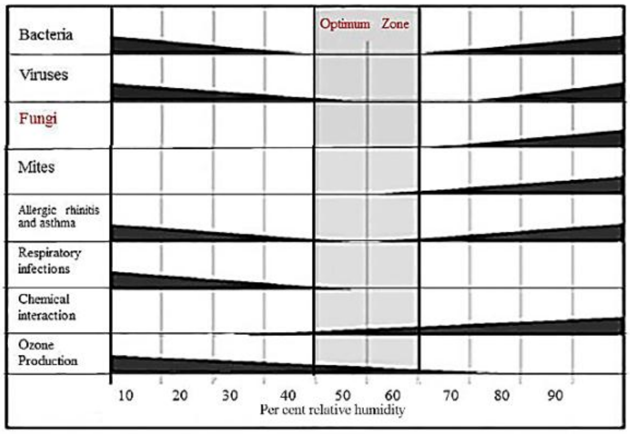

Fig. 1 Range of the fungi and bacteria growth in the air [13]

The high air humidity effects dried agricultural products in terms of the fungi which easily takes place in such condition causing the products to have low quality. Therefore, to solve the problem of drying using traditional drying methods such as solar drying, in which the air condition is uncontrollable, a new type of drying method which operates at temperatures not exceeding 35 ℃ is proposed and the properties after drying is studied. When the relative humidity is higher, it can be seen that the amount of fungi and bacteria increase. Fungi and bacteria cannot grow when the humidity is in the range of 40 – 60 %Rh. Therefore, the relative humidity must be kept in this range for dried shrimp to be safe from fungi. As a result, the water activity (a_w) in drying shrimp is equal to the relative humidity in the air. Under these conditions, new method for drying shrimp, which low-temperature dryings similar to heated air drying but does not involve heat. In daytime shrimp drying with sunlight and night time drying with low-temperature system, until moisture content of shrimp at 14 (%d.b.) The low temperature system is to reduce the relative humidity in the air by controlling the temperature at the surface of the cooling coil of air conditioning to below the dew point temperature, air is condensed into water drop as a result, the relative humidity of the air is low temperature. Dehumidification is carried out by applying an air conditioning system, working with a climate control unit to control temperature and relative humidity at 29-31 and 45-50% Rh, [14] respectively, for drying of shrimp during the night.

2. Materials and Method

2.1. Drying system

Despite solar dryer, the proposed low-temperature and low-humidity drying system has two main components: a 12000 BTU/h air conditioning system and a climate controller system. The climate controller system consists of an ultrasonic humidifier to increase water in the air, heater coil (2 kW) to increase temperature inside the room, inverter unit and microcontroller unit (MCU) to control a compressor in air conditioning system. The details show in Fig.2 the system is used for controlling relative humidity and temperature in chamber for drying shrimp.

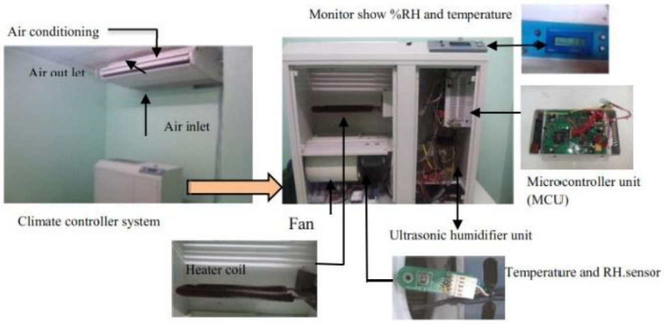

Fig. 2. Air conditioning and climate controller system

2.2. Details and system operation

From Fig. 3 the MCU (Microcontroller Unit) measures the temperature and the relative humidity (T_{exp},%Rh $_{exp}$) inside the chamber and compares the values with the set point relative humidity and temperature before the operation (T_{set},% Rh_{set}). If the relative humidity and temperatures exceed the setting values, MCU unit will turn on the compressor until the temperature and humidity are equal to the setting points and then the speed of the compressor begins to decline or turn-off. In this case where the humidity is reduced, the air temperature in the chamber will become lower as well. MCU will order electric heater to increase the air temperature in the chamber. In case the relative humidity in the air is lower than the set point value, the MCU will order the ultrasonic to operate in order to increase the quantity of water vapor in the air until it reaches the setting and then ultrasonic turns off [15].

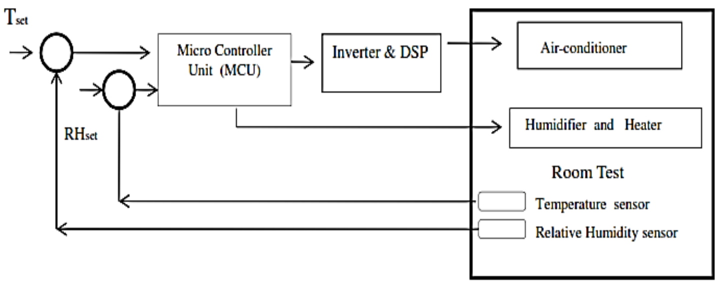

Fig. 3 Functional diagram with MCU and Inverter DSP [15]

2.3. Greenhouse drying

The greenhouse solar dryer was installed at School of Energy, Environment and materials. The dryer has a width of 0.60 m, length of 1.50 m and height 0.5 m. The dryer consists of a parabolic roof structure made from Polypropylene, which can be found in local. The dryer has the capacity of 3 kg of fresh product. The pictorial view of the dryer is shown in Fig. 4

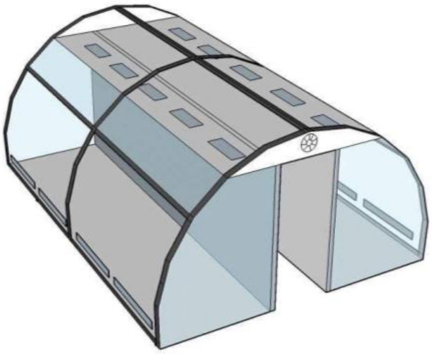

Fig. 4. Greenhouse dryer

2.4. Experimental

The drying is acted using the shrimp purchased from the local markets and selected the best ones. The tested shrimp with a length of 5-7 cm, as shown in Fig.5. In this experimental 300 g of shrimp, the initial moisture content 380% (d.b) was ready to drying operation in the greenhouse and Low-temperature drying process. For the daytime, the shrimp is dried inside the drying chamber by using hot air resulted by the solar drying and in the night time which Fig.5 using Low-temperature system for drying shrimp in chamber, by chamber is 16 m^2 size. This system controls the temperature (27-31 ^{O}C) and relative humidity (40-45 %Rh) during shrimp drying, by air conditioning system coordinate with climate control unit as show Fig.3 until the final moisture content of 14 %d.b. The determination of moisture content of shrimp is acted by measuring the weight of shrimp after the drying in every 1 hours until the weight of shrimp are not changed. The initial moisture content was determined by the oven method at 103 ℃ for 72 h., The shrimp 's moisture content is calculated from weight loss of shrimp samples according to AOAC standard (1995) [16]. The temperature and relative humidity in the chamber is recorded using a data logger Wisco DL 2000 (4 channels) every 10 minute. The velocity of air into or out of the cooling coils is measured using Anemometer AM4206 at 3 m/s.

Fig.5 Sample of shrimps used in drying

2.5. Moisture content [17]

Food moisture analysis involves the whole coverage of the food items in the world because foods are comprising a considerable amount of water rather than other ingredients. Foods are vital components which are consumed by the people at each and every moment for the surviving in the world. Basically there are several kinds of foods are available for the consumption as raw foods, processed foods and modified foods in the market. Moisture content of the food material is important to consider the food is suitable before the consumption, because moisture content affects the physical, chemical aspects of food which relates with the freshness and stability for the storage of the food for a long period of time and the moisture content determine the actual quality of the food before consumption and to the subsequent processing in the food sector by the food producers

Dry basis (%d.b.) is an expression of the calculation in chemistry, chemical engineering and related subjects, in which the presence of water is ignored for the purposes of the calculation. Water is neglected because addition and removal of water are common processing steps, and also happen naturally through evaporation and condensation; it is frequently useful to express compositions on a dry basis to remove these effects. Calculate the moisture content on dry based using the following formula equation 1:

$$\%d.b. = \frac{W - D}{D} \times 100 \tag{1}$$

Where W is the initial weight before drying process at time t, kg; and D is the final weight after drying process at time t, kg wet basis moisture content can range from 0 to 100 percent. Wet basis moisture is used to describe the water content of agricultural materials and food products. When the term "moisture content" is used in the food industry it almost always refers to wet basis moisture content. Calculate the moisture content on dry based using the following formula 2 :

$$\%w.b. = \frac{W - D}{W} \times 100 \tag{2}$$

Where W is the initial weight before drying process at time t, kg; and D is the final weight after drying process at time t, kg

2.6. Colors measurement [18]

The colors of the dried samples were assessed using colorimeter (WF32). The color system used was hunter lab where "L" is a measure of lightness, "a" is a measure of redness ("-a" implies greenness), and ''b'' is a measure of yellowness ("-b" implies blueness). For each drying experiment color measurements were taken on five dried and deshelled samples at three positions: P1 (by the head) to P3 (by the tail). The average of 5 measurements of each color parameter (L, a, b) was reported. All experiments were performed in duplicate. Colors change was then calculated by equation 3 :

$$\triangle E = \sqrt{(L - L^*)^2 + (a - a^*)^2 + (b - b^*)^2} \tag{3}$$

2.7. Texture measurement [19]

Texture of dried and deshelled samples was analyzed by shear test and uniaxial compression test. The shear test was carried out using a TA-XT2i Texture Analyzer (Stable Micro Systems, Haslemere, England). The force required to cut through an individual dried shrimp was measured using a Warner-Bratzler (WB) shear blade with an angular triangular slot cutting edge. The crosshead speed used was 2 mm/s and the distance travelled by the blade through the whole sample thickness and through the base plate slot was 20 mm. The maximum shear force was recorded. Three measurements were taken each at three positions. The value of hardness was defined as a maximum compressive force at 85% strain. The texture test was repeated 5 times for each drying condition and the average value was reported.

2.8. Shrinkage Measurement [20]

The measurement of shrinkage was performed by manually measuring the sizes of dried shrimp samples obtained from different drying processes (SD, GD, LD, SCLD, GCLD and MG) using a vernier caliper (by measuring each sample at three positions: length, width, and thickness). The equivalent spherical diameter of each sample was then determined and compared. Ten samples were taken for measurement for each experimental condition. All experiments were performed in duplicate. Percentage of shrinkage was then calculated by equation 4 :

$$\%Shrinkage = \frac{V_0 - V}{V_0} \times 100 \tag{4}$$

where V_o and V are respectively the sizes of shrimp at the beginning and at the end of each drying experiment. The volume of sample was measured using a pyrometer with n-heptane as the working liquid. The dried sample was weighted and filled into the pyrometer. The sample volume was calculated using the following equation 5 : [21]

$$V = \frac{\left[m_{ph} - m_p\right] - \left[m_{phs} - m_p - m_s\right]}{\rho_h} \tag{5}$$

The average value of the three sample was reported.

2.9. Water activity [22]

The application of water activity has become omnipresent within food science and related disciplines. It serves as a useful indicator of the microbiological stability of foodstuffs and food-related systems, much better than mere water content. Water activity also plays an important role on the sensorial properties of foodstuffs such as aroma, taste and texture as well as on their chemical and biological reactivity (e.g., lipid oxidation and non- enzymatic activity) [23]. Despite serious criticisms on the utility of water activity as a fundamental descriptor of water-related phenomena in food and related systems, it continues to be widely used to this day as a tool for product development and quality control across multiple areas of the food industry [24]. However, what water activity really is on a microscopic scale is still a matter of controversy, which we focus on exclusively in this paper. There are the following three different views co-existing in the literature:

1. The fraction of free or available water due to the presence of the bound water around solutes (sugars or polyols)
2. The measure of water structure formation or the ordering of water in the presence of the solutes (sugars or polyols)
3. The measure of hydration water which comes from the stoichiometric clustering/bindings models of water and solutes.

For the water activity can calculated by equation 6 ; [25]

$$a_w = \frac{N_{H_2O}}{N_{H_2O} + N_{solute}} \tag{6}$$

Where N_{H_2O} is moles of water and N_{solute} is moles of dissolved solute. For dilute ideal solutions only

3. Results and Discussion

3.1 Intensity of solar radiation

For this research, the experimental was carried out from 8:00 AM to 18:00 PM on the day clear sky conditions without rain. The experiment showed that at 8:00 AM onwards, the intensity of the sun's rays is increasing until about 13:00 – 14:00 PM each day. Experimentation will be the period with the highest solar radiation intensity. The highest value on August 22, 2017 was 1098 W/m^2. After this period the intensity of solar radiation will be reduced by the intensity of solar radiation is low, this will cause the internal temperature drying system is low, which is not suited to the drying out of the Fig. 6 It is noted that the value of the sun's radiation intensity on a daily basis will vary.

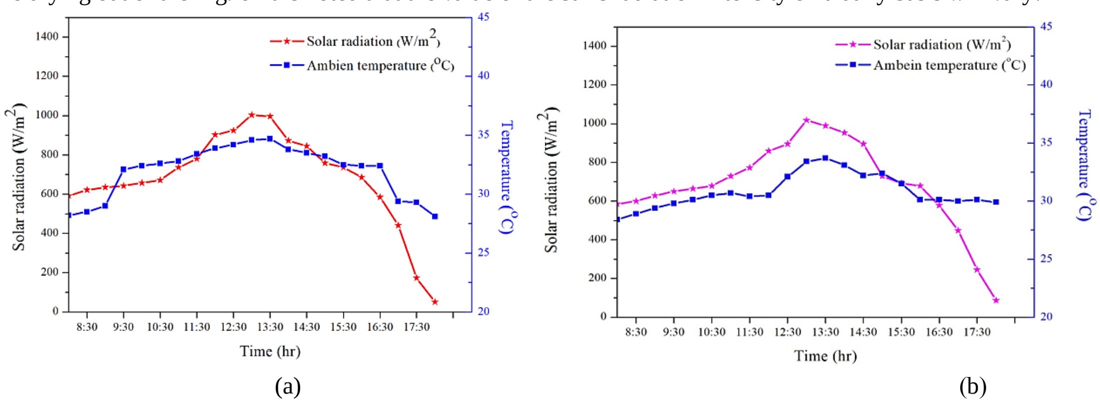

Fig. 6. Variations of the solar radiation with temperature during a typical experimental run
(a) 21 Aug 2017 and (b) 22 Aug 2017

Fig. 7 shows the comparison of the temperature changes at different positions inside the greenhouse dryer for a typical experimental run of solar drying of shrimp

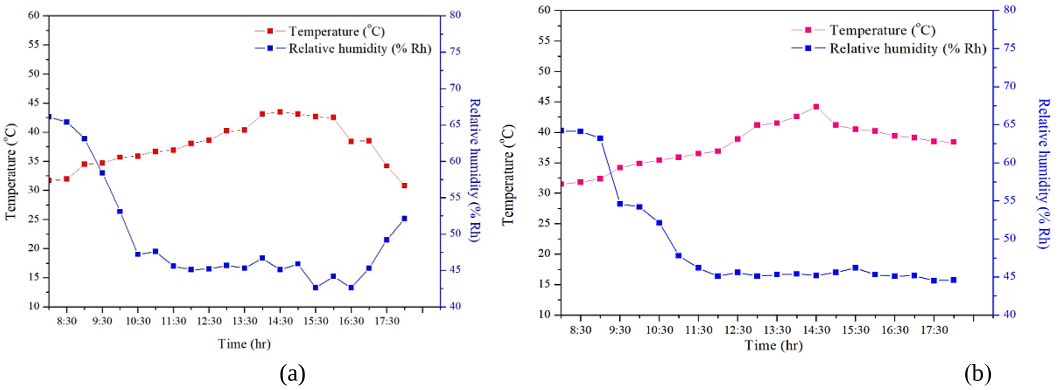

Fig.7 The relationship between the temperature and relative humidity of greenhouse drying. (a) 21 Aug 2017 and (b) 22 Aug 2017

The temperature of dryer was a parameter considered during the experimental drying of shrimp. Fig. 8 (a) shows the evaluation of air temperature of dryer chamber during experimental drying of shrimp. The drying chamber temperature range was around 27.7°C to 30.5 °C and an average chamber temperature was about 29.8°C. In Fig.8 (b), relative humidity of dryer considered during the experimental drying of shrimp was 42.6 % to 47.3 % with average about 44.52 %

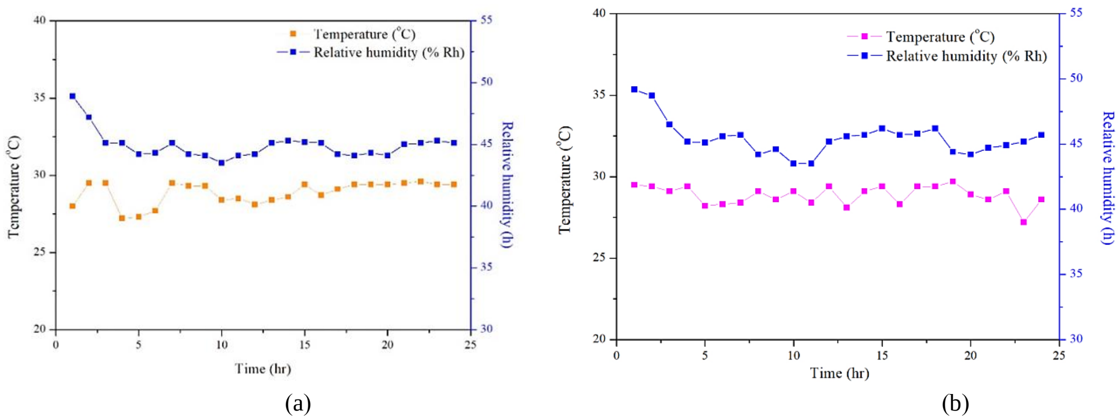

Fig. 8. Air temperature and relative humidity 21 Aug 2017 and (b) 22 Aug 2017

3.2. Color quality

Table 1 shows the color qualities of different drying methods. It was found that the L values of all 5 drying cases ranged from 32.03 to 35.37 Low moisture content is similar to low humidity drying. This is no different than statistically ($p > 0.05$), but the dried shrimp in 5 cases, the L value is lower when compared to the thinness of the market generally, where the drying of the 5 cases ranged from 16.97 to 18.21 which is no different than statistically ($p > 0.05$) which is higher compared to the shrimp at the market, The a which have an average of 16.57 to 18.12 and in the division. The b values were shrimp drying process and 5 cases ranged from 17.46 to 18.84 which is not much different statistically ($p > 0.05$). For the statistically is the reliability of the data for color analysis of shrimp after drying showed that the drying method was not significantly different from that of shrimp.

Table 1 Shows the color quality of shrimps drying method.

Drying method	Colors		
	L	a	b
Sun drying	32.03±6.71^{b}	16.97±3.21^{a}	18.25±2.37^{a}
Greenhouse drying	33.93±6.61^{b}	17.01±3.11^{a}	18.49±0.71^{a}
Low humidity drying	35.37±5.25^{b}	17.29±3.49^{a}	18.53±0.63^{a}
Sun drying combined with Low humidity drying	32.49±5.34^{b}	17.02±6.44^{a}	18.84±3.72^{a}
Greenhouse drying combined with Low humidity drying	34.51±5.03^{b}	18.12±3.42^{a}	17.46±6.38^{b}
General Market	41.31±2.16^{a}	16.57±1.37^{a}	14.81±0.71^{a}

*L,a,b Means in the same column with different superscripts are significantly different ($p < 0.05$).

3.3. Hardness

The Fig.9 shows texture measurement is a feature of food resistance to the action. The hardness characteristics depend on the measurement method. The wages expressed are the maximum wages, depending on the specific method of measurement. The size of the probe and the distance measured are measured by this experiment. Texture analyzer texture meter, using cutting blade length 10 cm move to cut supplies considering the hardness before the material fracture. The readable values are shown in graphs showing the force applied to the shear. It was found that drying of green shrimp with low moisture The highest hardness was 152.49 N, as a result of the first greenhouse drying in the daytime and drying. Low humidity at night at this stage, the temperature inside the dryer is high, so the evaporation rate is fast.

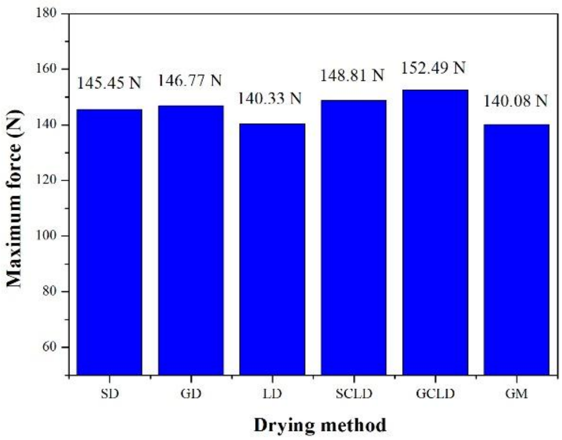

Fig. 9. Hardness of dried shrimp undergoing different drying method.

3.4. Water activity

Water activity is used as an indicator of the microorganism's ability to be growing in the agricultural products. Exceeding the standards will affect the duration of storage products based on the community standard (136/2558), which stipulated that. Must be less than 0.6 of the measurement results Quartet's App Activity of shrimp after the drying process of the 5 ways now that the Quartet's App Activity does not exceed 0.6. However, we will find that. Shrimp that we put to the test by buying from the market to the Quartet's Activity hit more than 0.6 which is under the risk of microbial growth shows in Fig. 10 However, even if the walk w Torre Activity will hit into the standard criteria should be adjusted to the lower humidity 15% (d.b.) It was the quartet's activity hit lower 0.6 and safe to keep the product.

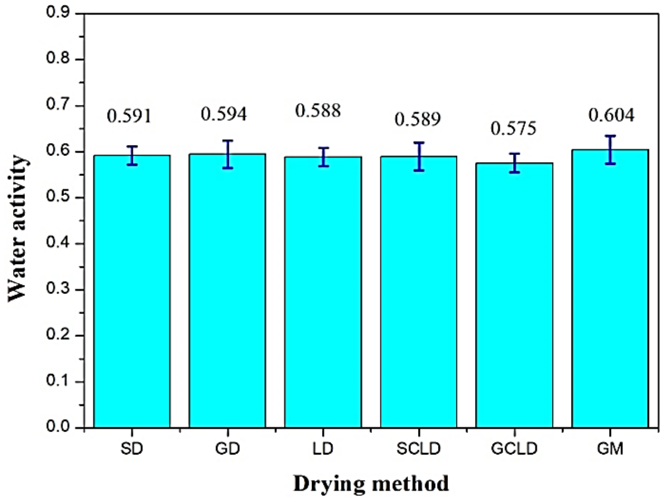

Fig.10 Water activity of dried shrimp undergoing different drying method.

3.5. Moisture content

Fig. 11 Shows the moisture change of each drying method. It was found that greenhouse drying combined with low moisture drying took only 16 hours to dry. The final moisture content of the shrimps was 13.41 (% d.b.). The change in moisture content of the shrimps between greenhouse drying and low moisture drying was significantly lower. Since the greenhouse drying process is a high temperature drying process, as a result, the rate of heat transfer from the medium to the product increased. This results in a higher evaporation rate.

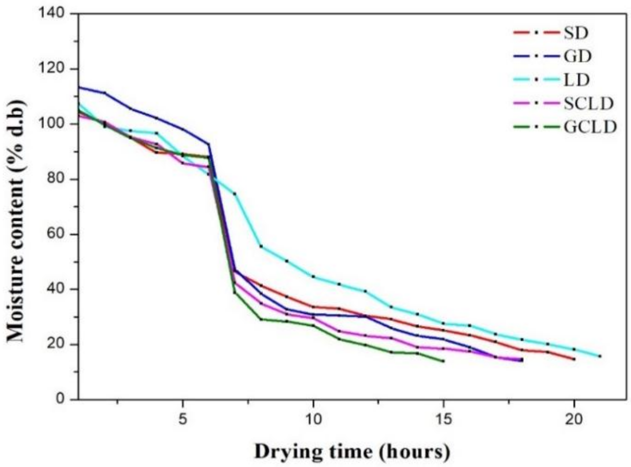

Fig.11. Moisture content of dried shrimp undergoing different drying method.

3.6. Shrinkage

During drying foods undergo volume changes either by shrinkage, which is due to the removal of water from the drying materials or by expansion, which is due to the pore formation. The different drying method thus provide different degrees of volume changes. Normally, the muscle fibers shrink as they lose moisture during drying.

Table 2 Shows percentage of shrinkage of shrimp drying method.

Drying method	Shrinkage (%)		
	Width	Length	Thickness
Sun drying	0.37±3.02	2.75±4.34	0.47±2.14
Greenhouse drying	0.33±3.14	2.59±2.21	0.44±2.58
Low humidity drying	0.41±3.14	3.92±2.14	0.49±3.14
Sun drying combined with Low humidity drying	0.25±2.51	2.17±0.21	0.31±2.12
Greenhouse drying combined with Low humidity drying	0.21±0.51	2.01±0.41	0.22±2.04
General Market	0.19±2.18	2.31±3.59	0.23±2.31

4. Conclusions

In this research, the greenhouse drying together with low moisture drying was studied. To study the feasibility of drying conditions and conditions, it was found that greenhouse drying combined with low humidity air took only 16 hours to dry. Compared to other drying methods, the advantages of this common drying method are the prevention of dust contamination as well as disturbance of insects. It was found that the drying time was short enough to cause the moisture to decrease. The initial moisture content of shrimp was 380 (%d.b.) and the final moisture content of shrimp was 13.41 (% d.b.). The brightness was 34.51 ± 5.03^{b}. Compared with other types of drying. They found similar values. The values were not significantly different ($p > 0.05$). It was found that greenhouse drying with low moisture drying had the highest hardness of 152.45 N. This is the result of temperatures in the drying house, which may be as high as 48.7 ^{O}C at 14:00 PM as a result, the water evaporates quickly, the texture of frozen shrimp. For water activity is 0.575 this is a standard that indicates that fungi or microorganisms are not growing at this stage. The dried seafood will then have to be water activity close to 0.6

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