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THIN-LAYER DRYING OF SHRIMP BY-PRODUCTS

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ABSTRACT

Shrimp by-products from shrimp processing industry could be a good source for production of bioactive compounds as protein, lipid and minerals. The present study aimed to drying shrimp by-products (head and shell) which represent about 40 –50% from total weight. The dry parameter was drying air temperature (50, 60, 70 and 80°C) and drying air velocity (1, 1.5 and 2 m/s) at thickness layer of 8 mm. The results indicated that the initial moisture content of 180% (d.b) decreased to a range between 10 and 8 % (d.b) at the end of drying process depending on the drying conditions. For instance, the shortest drying time was at 150 min, 80°C drying air temperature and 2 m/s air velocity. While, the longest drying time was recorded at 360 min with 50°C and 1m/s air velocity.

INTRODUCTION

Shrimp *(penaeusvannamei)* by-products is a high source of protein (50%) and it undergoes rapid disintegration which leading to environmental pollution. It is necessary to preserve the material adopting the environmentally safe techniques. Shrimp processing for freezing normally involves removal of head and body carapace. Processing of shrimps produced large quantities of solid wastes. The solid shrimp waste contains head and body shell represents approximately 40-50% of whole shrimp weight. The tropical shrimps, the head generally constitutes of 34-45% and body shell constitutes of 10-15% **(Barratt and Montano1986)**. It was found that the shrimp by-products can be used as a raw material for extraction of chitosan and lipid-mineral-rich carotenoprotein by combining chemical and biological treatment.

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Chitosan has been recognized as a multifunctional bioactive compound and has been used widely in food, biotechnology, cosmetics and medicine. Lipid-mineral-rich carotenoprotein can be used as a supplement in food and aqua-feed with good nutrional and functional properties.

The results proved that high quality chitosan and lipid-mineral-rich carotenoprotein can be obtained from shrimp by-products (**Trang and Phuong, 2012**). Shrimp by-products with high economic value is considered as containing a high proportion of protein. As a result of neglect, lack of recycling is not take advantage of them and cause pollution of the environment with a high degree where it is fast decomposition produces odors and gases are corrupt. In some cases, shrimp by-products up to 50 % of the shrimp mass. So now the world tended to recycle the by-products for use in different areas (diet poultry and shrimp diet). Total Egyptian shrimp production was about 21.8Gg 35-45% of this amount is by-product (**GAFRD, 2014**). **Sobukola and Olatunde (2011)** mentioned that drying of shrimp is important, because it preserves shrimp by inactivating enzymes and removing the moisture necessary for bacterial and mould growth. The safe moisture content for shrimp meal storage was lower than 12% db. It is important, for digestibility of shrimp meal, to maintain moisture around the protein. To accomplish this, it is essential to keep the maximum product temperature inside the dryers below 100°C. If protein is over heated the amino acid structure will change. As a result, the protein is not easily recognized nor absorbed by the intestines of the animals. From a practical point of view, overheating of the fish meal makes the fish meal less digestible. **Zhiqiang et al. (2013)** reported that the hot convective drying of fresh tilapia fillets was evaluated in a heat pump dryer. The influence of the drying temperature (35, 45 and 55°C), hot air velocity (1.50, 2.50 and 3.50 m/s) and thickness (3, 5 and 7 mm) of the tilapia fillets on the moisture ratio and drying rate have been studied. It shows that drying process took place in falling rate periods. The experimental drying data of fresh tilapia fillets under different conditions was fitted to nine different commonly used thin-layer drying models. Constant drying rate period was not observed; the drying process took place in the falling-rate period. With the increase of the drying temperature, drying velocity and reduction of the thickness, the moisture ratio decreased and the drying rate increased.

The main objectives of this study were:

-Thin-layer drying characteristics of shrimp by-products using the thermal dryer at different air temperature and hot air velocity.
- Estimate drying cost of the dried shrimp by-products.
-Chemical analysis shrimp by-products.

MATERIALS AND METHODS

1. Shrimp by-products: Raw material by-products were obtained from Alobor market in the province of Cairo, Egypt. The by-products transfer immediately in plastic boxes containing crushed ice to the lab and packed in polyethylene bags and stored at -18°C until the time of the experiment. Before any experimental range, by-products taken from the refrigerator and placed in the laboratory to achieve the ambient air temperature.

2. Unit drying:

This unit was developed, constructed by **Galal (2015),** of the Faculty Agricultural Engineering, Al-Azhar University, Nasr City, Cairo, Egypt. The dryer was fitted with a temperature control system. The dryer consists of. (Fig. (1)).

1. Forced air section: A small air blower of 300 W, 220 V, made in China was used to supply the hot air flow rate. This blower connected to the air heating section.

2: Air control gate: Section of the steel sheet thickness of 10 mm moving up and down through the spiral nail to pass the amount of air required.

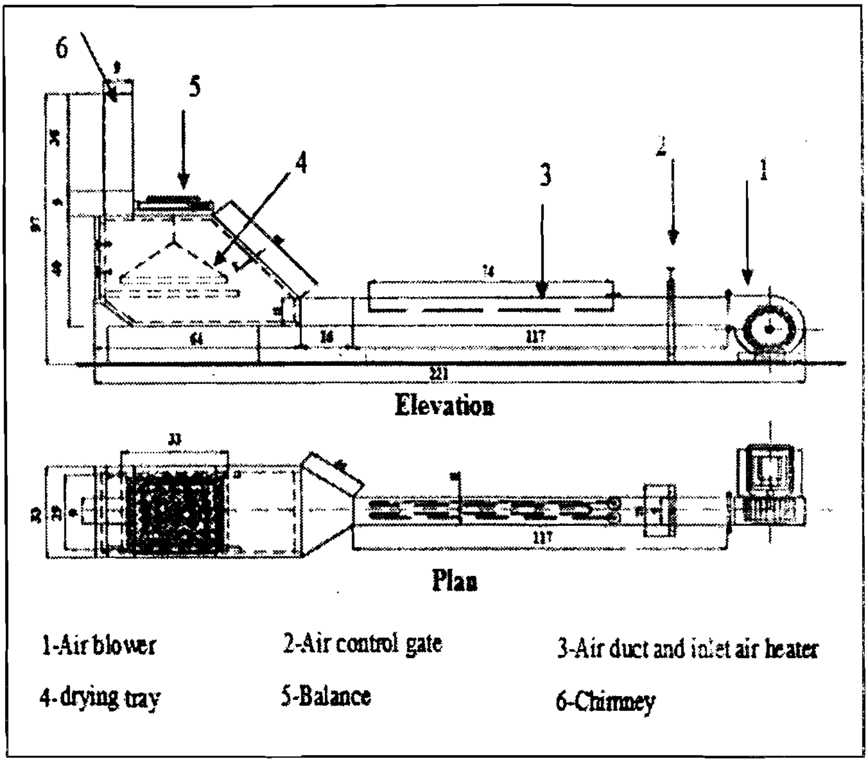

Fig. (1): Elevation and plan of unit drying.

3. Tray drying: Made of a fixed aperture wire mesh of galvanized steel for entering hot air to product parts, dimensions of 330 × 270 mm framed of wood thickness of 30 mm rectangular shape.

4. Air heating section: Room with dimensions of 1300mm length, 100mm width, 100 mm high made of galvanized steel sheet of 0.5 mm thickness and insulated from the outside by glass wool with thickness of 30 mm to prevent heat loss. The electrical heater of 3 kW (U form) was fixed inside the housing to heat the drying air.

5. Drying section: The drying chamber was constructed of wooden panels 400x330x300 mm (20mm thick), the side walls and bottom of drying chamber were insulated by foam layer. Drying air inters the chamber after leaving air heating section through an air duct from the bottom to

the top of the dryer bin. The dryer door was made of wooden panels with dimensions of 330 mm long and 300 mm wide, the door was connecting to drying chamber by two hinges and tightly sealed by a rubber gasket during the drying process. Drying was mounted on a wooden stand of 800 mm height from the ground.

3. Measurement instruments:

1. Digital veneer caliper: To measure dimensions (Accuracy of 0.01mm).
2. Electric oven: with the following specifications (VENTICELL55 type, 230V, 50/60 Hz, 1250w, 250Max.tempruture) is used to determine the moisture content of by- products samples, at 105°C for 24 hour drying time.
3. Anemometer: To measured air velocity inside the drying chamber (Range from 0 to 44 m/s, accuracy of 0.1m/s).

4. A digital balance was used for measuring the weight of the sample of by-products during drying (5 kg with sensitivity of 0.1 g).

5. Temperature control device: Is connected to the temperature sensor inside the drying chamber for temperature sensor drying air temperature. This sensor is connected to a digital thermostat. Digital thermometers (a type of Dixell, not a model "XR10CX - 5N0C0" with accuracy of 0.1°C. The sensitivity ranged from 0.1 to 2°Cand work in a temperature range of 0-400°C.

4. Initial moisture content of samples:

Initial moisture content of samples was determined by oven at temperature of 105 °C for 24 hours **(AOAC Standards, 2005)**. It can be calculated as follows:

$$M_{td} = \frac{W_m}{W_d} \times 100 \qquad \text{.................................} (1)$$

Where:

M_{td} = Moisture content dry basis (%).

W_m= Mass of water in sample (g).

W_d = Mass of dry material (g).

2. Moisture cortent at any time (m_t), (wet basis %):

The moisture content, wet basis % is determined every 30 minutes as follows:

$$\grave{A} = A\,(1 - m_{iw}) \qquad \text{..........................(2)}$$

$$m_t = \frac{B - \grave{A}}{B} \qquad \text{..............................(3)}$$

Where:

A'= Mass of dry sample (g).

A= Mass of fresh sample (g).

B = Mass of sample at any time (g).

m_{iw} = Initial moisture content, w b (%). **(Tayel et al., 2012).**

3. Moisture content (M_t), (dry basis %):

The moisture content, dry basis % is determined every 30 minutes as follows **(Tayel, et al., 2012)**:

$$M_t = \frac{B - \grave{A}}{\grave{A}} \text{.......................................(4)}$$

4. Moisture ratio (MR)(db %) and drying rate constant, (k): The Drying rate constant (k) is determined as follows**(Lewis, 1921):**

$$MR = \frac{M_t - M_e}{M_i - M_e} = e^{-Kt} \text{..................................(5)}$$

Where:

M$_i$: Initial moisture content, % (db).

M$_t$: Moisture content at any time during drying, % (db).

M$_e$: Equilibrium moisture content, % (db).

k: Drying rate constant, min^{-1}.

t: Drying time, min.

Determination of the drying rate constant, (k): By using equation (5), "k" was expressed in a linear form as follows:

$$\ln MR = -Kt \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

So, plotting $\ln MR$ vs. t results in a slopping down straight line whose slope is **k**.

5. **Cost analysis:** The dryer hourly costs were calculated based on the fixed costs and variable costs of convection dryer by using the following formula **(Awady et al., 2003)**

$$C = \frac{P}{h}\left(\frac{1}{a} + \frac{i}{2} + t + r\right) + (W.e) + \frac{m}{200} \qquad \ldots\ldots\ldots\ldots\ldots (7)$$

Where: C = Dryer hourly cost, L.E. /h, P =Price of dryer, L.E., =500 L.E, **h** = Yearly working hours, which were is assumed in the present work to be:(300 day/year x 2 period/day x 8 h/period = 4800 h/year) , a = Life expectancy of machine, about (10 Year), i = Interest rate/Year. (The bank interest in Egypt), which was about 11%, t = Taxes and overheads ratio, which is assumed in the present work to be 20 %, r= Repair and maintenance ratio, which is assumed in the present work 10 %., W = Power of dryer (kW), e = Hourly cost/kW. h, (0.85 L.E./kW. h),**m** = The monthly average wage, L.E., (1000 L.E), impose that here are 10 dryers becomes (100 L.E./man. dryer, month), **200** = The monthly average working hours.

$$Cost(L.E/Kg_{dried\ product}) = \frac{Dryer\ hourly\ cost(L.E/h)}{Dryer\ productivity(kg_{dried\ product}/h)} \ldots\ldots (8)$$

RESULTS AND DISCUSSION

6. Behavior of the convection drying regimes:

6.1. Evaluation of the effect convection air temperatures, thickness of the layer, and velocity on the product moisture content and elapsed time:

A single layer of shrimp by-products was dried in Thermal dryer under controlled condition of temperature, thickness of layer and air velocity. The drying experiments were conducted for temperature range of (50, 60,70 and 80) °C, thickness of layer 8 mm and air velocity range of (1, 1.5 and 2 m/s). General trend was observed where, the moisture content decreased with the increasing in drying air temperature, air velocity and drying time. The limited information is available on the kinetics of water removal from shrimp by-products. The decreased moisture content could be attributed to increased evaporation of water both on the surface and in the by-products due to increasing temperatures and velocities of drying air. Fig. (2) shows that the moisture content of 180 % (db) decreased to rang between10 and 8 % (db) at the end drying process depending on the drying conditions. For instance, the shortest drying time was recorded at 150 min with 80°C drying air temperature and 2 m/s air velocity. While, the longest drying time was recorded at 360min with 50°C and 1m/s air velocity. One drying model (Lewis's) has been used to describe drying curve. The model type, model constant and determination coefficient (R^2) of one different models used for moisture ratio change with drying time are presented in Table (1). Based on these results, the mode drying curves in all the treatments tested.

6.2. Drying constant (K):

Table (1) shows the drying constant values (k) obtained at different temperatures and air velocities of shrimp by-products. The correlation coefficient (R^2) ranging between 0.8609 and 0.9753, it is noted that the k values have been steadily increasing with the increase in both temperatures and air velocities. Figs (3) reveal the relation between (K) and (T) at different (V) the figure shows that the relation between (T) and (K) was exponential relation as:

$$K = aT^b \qquad \text{..................................} (9)$$

Table (2) and Fig (4) show the relation between parameter a, b and V it's clear that the relation was linear equation as:

$$b = -0.7746V + 2.6327 \qquad \text{...........................} (10)$$

From equation (9) and (10) the relation was as following:

$$K = 7.53E - 05T^{-0.7746V+2.6327}R^2 = 0.9452 \qquad \text{.................} (11)$$

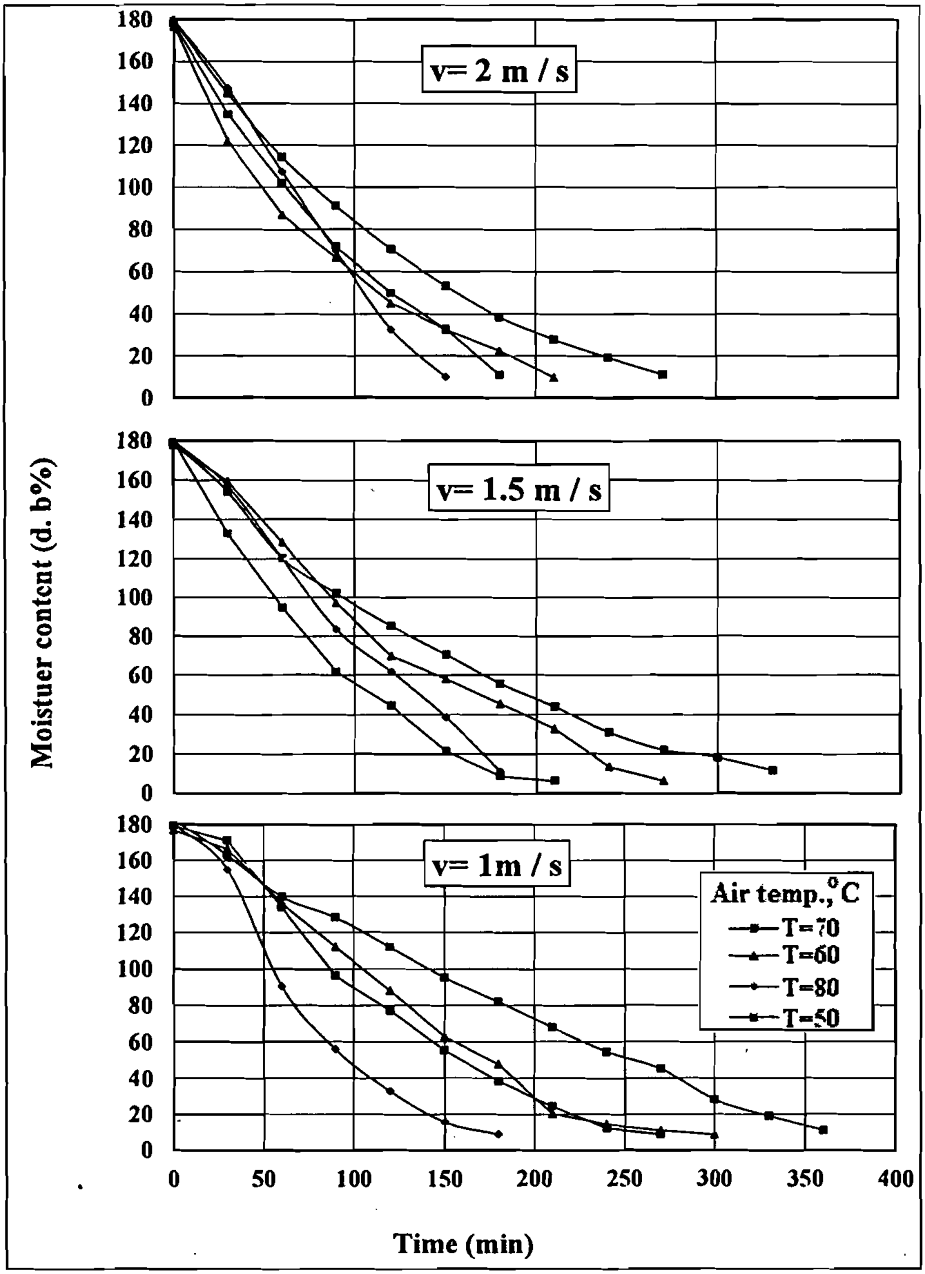

Fig. (2): Moisture content (db %) as related to drying time (min) at different velocities (m/s) and drying air temperature (°C).

Table (1): Drying rate constants.

Velocity m/s	Temperature °C	K (min^{-1}) Drying constant
2	80	0.0183
	70	0.0149
	60	0.0144
	50	0.0107
1.5	80	0.022
	70	0.0189
	60	0.0147
	50	0.0106
1	80	0.0183
	70	0.0116
	60	0.0112
	50	0.0071

Table (2): Parameters (a) and (b) at different air velocity (v).

v (m/s)	a	b
2	2.00E-04	1.0564
1.5	2.00E-05	1.5249
1	6.00E-06	1.831

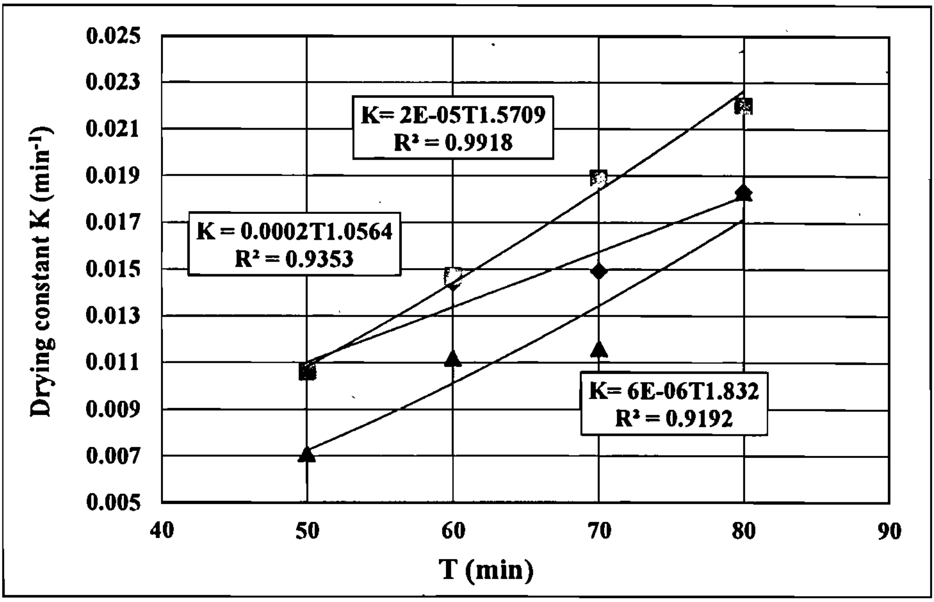

Fig. (3): The relation between drying time (T) and drying constant (K) at different air velocity (v).

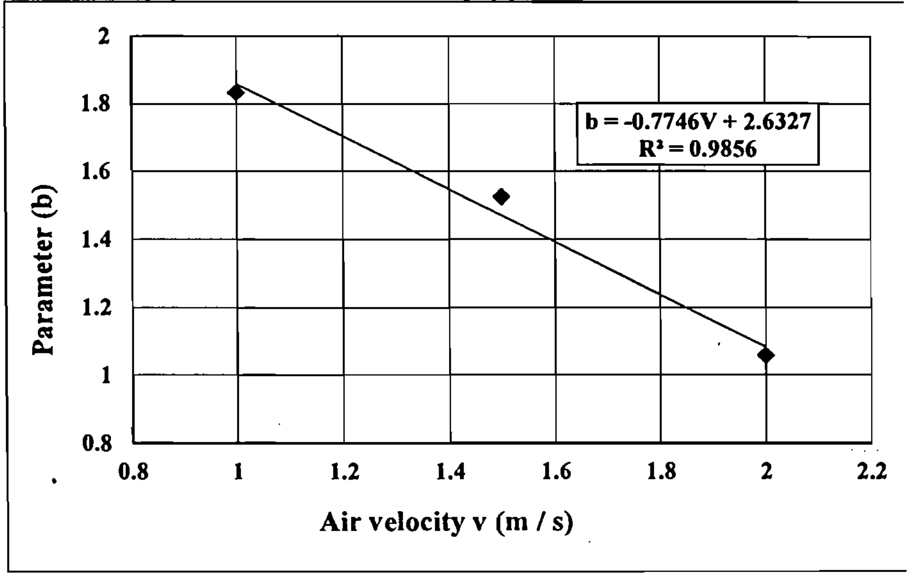

Fig. (4): Relation between parameter (b) and air velocity v (m/s).

From equation (11) and (5) the relation was as following:

$$M\,R = e^{-\left(7.53E-05T^{-0.7746V+2.6327}\right)t} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (12)$$

7. Costs analysis:

The operating cost (LE /h) for the convection dryer and the costs of kilogram dried product for shrimp by-product by equation (7) and (8). The costs for were calculated at the drying conditions that achieved the highest quality of the product and less drying time.

The operating cost of convection dryer was 1.3402 LE/h and the cost of kilogram dried product 5.843 LE /kg at dried air temperature of 80 °C and Air velocity 2m/s.

8. Chemical analysis:

The chemical analysis of shrimp by-products based on dry basis, as shown in table (3).

Table (3): Chemical analysis of shrimp by-products.

components	Contents
Protein (%)	**54.4**
Chitin (%)	**9.3**
Minerals (%)	**21.2**
Lipid (%)	**11.9**
Carotenoids (mg/kg)	**206**

CONCLUSION

The main objectives of the present work are to Study installation thermal dryer to drying shrimp by-products to studying of factors affecting in the drying was done. Study the results and agreement with some previous studies such as formula (Lewis's). Drying constant finding of this formula. Determine the quality of the product through chemical and economic analysis.

So it was studied

Installation thermal dryer to dry the shrimp by-products at different variables as air temperature (50, 60, 70 and 80°C) and velocity drying air (1, 1.5 and 2 m / s).

The important results:

1- The shortest drying time was recorded at 150 min with 80°C drying air temperature and 2m/s air velocity. While, the longest drying time was recorded at 360 min with 50°C and 1 m/s treatments.

2- One drying model (Lewis's) has been used to describe drying curve. The modified simple model was found to be the best fitted model to describe the drying curves in all the treatments tested.

$$K = 7.53E - 05T^{-0.7746V+2.6327} R^2 = 0.9452$$

3- Results illustrated the cost of a kilogram of dry shrimp remnants of 5.843 LE. At temperature of 80 °C and air velocity 2 m/s.

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الملخص العربي

تجفيف طبقة رقيقة من مخلفات الجمبري

فتحي ابراهيم زبادي *

ينتج من تجفيف الجمبري كميات كبيرة من المخلفات التي ليس لها قيمة اقتصادية وتؤثر على البيئة في إنتاج روائح وغازات كريهة. ويمكن الاستفادة من هذه الكميات الكبيرة من المخلفات كأحد مكونات البروتين الحيواني في علائق الدواجن والأسماك عن طريق التجفيف والطحن.

لذا كان الهدف من البحث تجفيف مخلفات الجمبري عند محتوى رطوبي ابتدائي ١٨٠٪ على أساس جاف، في طبقة رقيقة باستخدام مجفف ميكانيكي يعمل بالكهرباء، وتحت تأثير اربعة مستويات مختلفة من درجة حرارة هواء التجفيف وهي ٥٠ – ٦٠ – ٧٠ – ٨٠ °م وثلاثة مستويات من سرعة هواء التجفيف وهي ١- ١,٥–٢ م/ث، ثم دراسة فاعلية تلك العوامل على فقد الرطوبة، وزمن التجفيف، ومعدل التجفيف، ونسبة الرطوبة لمخلفات الجمبري.

وقد تم اختبار نموذج لوصف عملية تجفيف مخلفات الجمبري في طبقة رقيقة شملت معادلة "Lewis" تحت ظروف التشغيل المختلفة، كما تم تقدير تكاليف تشغيل المجفف والتحليل الكيميائي لمخلفات الجمبري المجفف، وكانت النتائج المتحصل عليها أن جميع معاملات التجفيف تزداد في معدل الانخفاض للمحتوى الرطوبي لمخلفات الجمبري وكذا زيادة معدل التجفيف لمخلفات الجمبري بزيادة كل من درجة حرارة وسرعة هواء التجفيف.

وبينت النتائج أن أقل فترة لتجفيف مخلفات الجمبري هي ١٥٠ **دقيقة** عند ٨٠°م لحرارة هواء التجفيف و ٢ م/ث لسرعة الهواء، بينما أقصى زمن تجفيف هو ٣٦٠ **دقيقة** عند ٥٠°م، ١ م/ث.

كما بلغت تكلفة تشغيل المجفف ١,٣٤ **جنية/ساعة**، وكانت تكلفة إنتاج مخلف الجمبري المجفف ٥,٨٤٣ **جنية/ كجم**، عند ٨٠°م لحرارة هواء التجفيف، ٢ م/ث لسرعة الهواء.

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