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Performance Assessment of Chicken De-Feathering Machine in a Small Scale Slaughtering Processors

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ABSTRACT

The demands of poultry meat in Egypt have imposed a great responsibility on the poultry processing industry especially in de-feathering operations. The energy and construction of the scalding and de-feathering machines are so essential innovation for the small scale poultry industry because they reduce the stress encountered within the manual de-feathering. Therefore, the aim of the current investigation is to discuss the behavior of the energy utilization efficiency of scalding and chicken feather removal machines in Egypt at small scale chicken slaughtering systems. This paper is focused on improving the efficiency of both the machines and the devices used in scalding and de-feathering operations by evaluating the used operational parameters of the machinery techniques, as well as investigating the rationalization of the energy used in small scale slaughtering process. The utilization efficiency of the de-feathering process was measured as the de-feathering machine was operating at various de-feathering drum speeds i.e., 290, 320 and 350 rpm by using three different chickens' weights under various scalding temperatures i.e., 60, 64, and 68oC. On the other hand, the force required for de-feathering was measured through an experiment set up for this purpose. The results indicated that the optimized operation parameters were found at: 680C scalding temperature, 0.7 m3/20 birds scalding water flow, 415 mm span between two de-feathering bands, 105s de-feathering time for the de-feathering machine and 320rpm de-feathering drum rotation.

***Keywords**: Energy utilization efficiency, scalding operation and de-feathering process.*

INTRODUCTION

The growing population and increasing continuous demand of chicken meat worldwide have imposed greater responsibility on the chicken meat processing industry. On the other hand, the effective mechanization of the poultry slaughtering process will achieve a great reduction in energy utilization as well as will lead to support quality, ergonomic, safe and economic slaughtering operations. So, various capacity machines for the poultry slaughtering process have been developed either for commercial or household use (Barbut, 2002 and Adesan and Olukunle, 2015). Chicken meat processing industry involves many processes i.e., pre-slaughter (catching and transport) followed by killing and bleeding then scalding followed by feather removal and picking followed by removing some parts (e.g., head, oil glands and feet) then evisceration, chilling, cutting and deboning, respectively followed by further processing like packaging, storage and marketing (Fanatico, 2003). Kiepper, (2003) stated that the scalding and de-feathering processes are the most time consuming as well as are the most energy-intensive unit operations and less risky and product quality especially when they are executed using small capacity machines.

Optimum energy usage is one of the big concerns in any manufacturing industry including the chicken meat processing industry (Barbut, 2002 and Osha, 2004). Jekayinfa, (2007) implemented an energy audit for three poultry processing plants and found that the scalding & de-feathering is the most energy-intensive unit process in all the three plant categories with 44% of the total energy consumption. While consuming energy via other processing operations were 17.5% for eviscerating, 17 % for slaughtering, 16% for washing & chilling and 6% for packing. Hung et al., (2011) determined the quality of the chicken products by measuring the percentage of the weights of feathers that remained on the chicken product under the circumstance of undamaged skin condition. The results illustrated that the temperature of scalding, as well as the distance between two de-feathering bands, possessed the most significant impact on product quality.

The objective of the current investigation is to execute the comparison among the energy utilization efficiency for both the machines and devices used in scalding and de-feathering machines in Egypt. This information may be help to realize a great reduction in energy utilization for scalding and de-feathering operations under small-scale poultry slaughtering processors.

MATERIALS AND METHODS

The current study was implemented in laboratory of the poultry production department, Fac. of Agric., Man. Univ., Egypt, which experimental conducted in small scale with capacity of 200 chickens per day. The operating systems that conducted on chicken Lab are slaughter & bleeding, scalding, removing feathers, removing head & feet and chilling & lately packaging processes. Typically, the most important of them are scalding and de-feathering due to their significant impacts on utilization efficiency and product quality. The energy utilization under above lab conductions namely, electricity that used to driven de-

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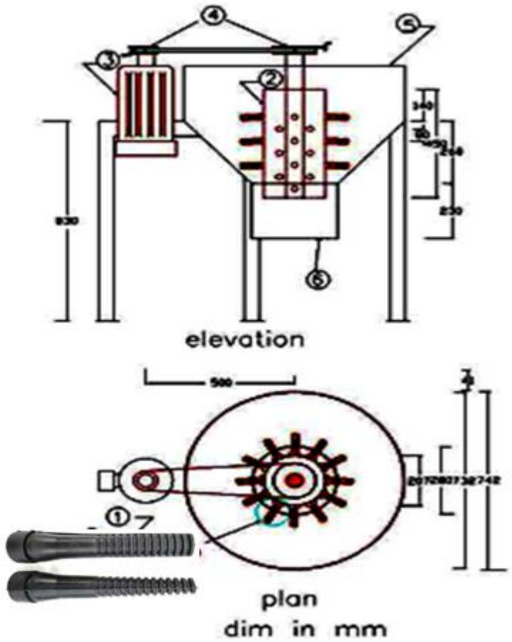
feathering device via an electrical motor and gas of propane "LPG" which used to generate hot water that needed for the scalding operation.

The devices description

The first device is scalding device "SD" includes a hot water metal boiler, a natural gas cylinder (LPG propane), a gas flow meter and a thermometer. The hot water boiler is cylindrical shape and filled with water which was heated by utilization of the combustion gas of the LPG (propane). The thermometer is used for checking intermittently both hot water and surrounding space temperatures.

The second is for de-feathering system is feather-plucking unit "DFP" that included the de-feathering chamber, rotating plucking mechanism, electric motor of 1.0HP, V-belt, pulley driven/drive power transmission system and frame. The sketched assembly diagram of "DFP" machine illustrates as shown in Fig 1.



1-plucking finger 2- rotating plucking drum
3- electrical motor 4- driver and dreven pules
5- tank 6-out feathers let

Fig. 1. Assembly diagram of de-feathering & plucking device

The electric motor was equipped on the frame side, while the belt-pulley drive arrangement was positioned at the top of the plucking chamber. The plucking mechanism includes a rotating galvanized steel drum of 440mm diameter, as well as it is studded with rubber fingers slotted as a series to rotate horizontally. It is driven via a driving shaft connected to the driving pulley that is powered using the electric motor via a belt transmission. The space which exists among the rubber fingers and the chamber inside the surface form the housing unit for the bird where the de-feathering operation will be executed. However, the rotating drum laden with the rubber fingers is subjected to a rotary motion by the transmitted torque from the electric motor. Therefore, the carcass is rubbed with the rubber fingers, and the feathers are thereby plucked continuously till the chicken is completely scalded. The speed of the drum was confirmed by a tachometer, where it was varied by means of a step turned pulley on the electric motor. The frame has a triangular shape as well as it bears the total weight of this machine.

Experimental procedures

The treatments were divided into two groups. The 1st group was devoted for investigating the scalding operation, whilst the 2nd was done for investigating the de-feathering operation.

Scalding process

The impacts of the bird's weight and the scalding temperature, as well as the surrounding air temperature on the energy utilization efficiency during executing the scalding operation were identified as follows:

1- The process was executed on three sequence days, where the boiler tank was filled with a water volume of 20 liters. The temperature of hot water was controlled to be various scalding temperatures "60, 64 and 68°C" per the 1st, 2nd and 3rd day of tests, respectively.
2- On each day, during the experiment execution, 60 chickens were processed, 20 chickens per average mass of 1250 and 1500 and 1750 g. That were collected and dipped in hot water with controlled temperatures. The 20 chickens divided into two groups (10 per group) which the first 10 of each weight category were put in hot water for 60 sec only, while the other ten chickens were put for 120 sec only. The scalding time was measured via a stopwatch.

De-feathering process

The experimental procedure of the de-feathering operation was separated into three sequences: -

Determination of feather plucking forces

Manually, the required feather plucking forces were conducted under different three mass categories "in average mass of 1250 and 1500 and 1750 g" and three scalding temperatures "60; 64 and 68C^{0}". After the scalding process, three scalded chickens that have just been soaked in hot water from each treatment were transferred directly to a wooden table equipped with a Digital Force Gauge. The body of each bride carcass sample was held then fixed into a wooden base on this table, where the hook of the force gauge was hitched to carcass feather by the usage of nylon wire. Then the hook has manually pulled the feather in the downward direction and the digital reading of the pull force was recorded. The average of the three measured force records was estimated to compare the required plucking force of a chicken's feather as influenced by chicken mass and scalding temperature traits.

Quantifying removing efficiency of feather

Mechanically, it was done under three chickens mass categories, three scalding temp and three drum speeds per three replicates. The feather plucked by the machine (for each de-feathered carcass) was collected then weighed via an electric weighting balance of 0.01g accuracy. In addition, after machine operation, the non-plucked feathers (The leftover feather on the bird) were plucked using a manual method then weighted for each processed carcass. Taking into consideration that these measurements were replicated three times as above mentioned, and the averages of obtained data were considered for estimating the removing efficiency of a chicken's feather.

Site description and energy caculations

To achieve the objective of the current study the following parameters were estimated, calculated and measured as following:-

Force required for plucking the feathers (F)

Generally, it was noticed that the force required for plucking out the bird wing feathers force is two, three, and five times larger compared to the forces required for plucking out the rear feather, the long body feather, and the short body feather respectively. Consequently, the forces required to pull out the wing feathers from different scalded and un-scalded live bird weights were considered for that test evaluation. These forces were measured using a digital force gauge (SHIMPO- Model DF-5.0) with accuracy □ 1 gram. This Force Gauge was calibrated by standard forces, and each individual wing feather was hitched in the gauge hook by nylon wire and then pulled it in the downward direction, the maximum pulling force was measured and recorded in a gram-force scale and after that, we get the corresponding force value in Newton. In tests, de-feathering velocity was measured by the optical RPM meter.

The efficiency of feather removal was determined as a percentage of the remained feather mass on the chicken body using the following equation:-

$$\boldsymbol{lucking\ Efficiency}(\mu)\ \% = \frac{W_{mp}}{W_{mp}+W_{np}}\times\mathbf{100}$$

Where; **W_{mp} = mass of feather plucked by machine, g ; W_{np} = mass of feather manually plucked the non-plucked feathers (The left over feather on bird).**

RESULTS AND DISCUSSION

Force required for plucking feathers (F)

Firstly, the experimental results for the chicken scalding and the de-feathering process will be provided. Then, according to the results of ANOVA, the impacts of scalding and de-feathering factors to feather remained on the birds product will be presented in the table (1). Finally, depending on the optimization solutions, the values of the optimized operational parameters of both scalding and de-feathering machines will be provided. Data in Table 1 illustrate the ranges of wet body masses and spring balance readings of pulling force required to detach the various feathers. The body weight ranged between1250–1750g. While the maximum pulling force required detaching the wing feather ranged in between 6.0–9.4N. Also descending pulling force values were 1.5–4.5 "Rf"; 1.8–3.1"Lf" and 0.3–0.8 "Sf" for rear feather, long body feather and short body feather, respectively.

Table 1. Ranges of wet body weights and spring balance readings of pulling force required to detach the various feathers

	Rf	Lf	Wf	Sf	Bm
	Feather pulling force (N)				
A	3±1.5	2.45±0.65	7.7±1.7	0.55±0.25	1500±250

A; average Rf; rear feather Lf; long body feather
Wf; wing feather Sf; short body feather Bm; body mass

Feather mass remained on chicken "Y1, %"

The scalding process is evaluated under the factors that influence of feather mass remained in percentage. Fig. 2 illustrate the surface plot of feather mass remained on chicken product " Y1,%" via each of "T; ts" as shown in Fig. 2-A; "ts; q" as shown in Fig 2-B and "q;T" as shown in Fig 2-C. Regarding to Fig. 2, the inversely relationship between feather mass remained and each of scalding temperature "T", scalding time "ts" and scalding water flow "q". Under drawing the above variables with response surface effect, the results indicated the scalding temperature possessed the strongest impact on product quality followed by the scalding time.

Regarding to Fig (2) and scalding time 90sec the Y1 recorded 7.48; 1.33 and 0.14% at "ts" of 60, 90 and 120s respectively with average chicken mass of 1750gram and contestant "q= 0.7m^3per 20 bird. The influences of scalding temperature "T", scalding time "ts" and scalding water flow "q" as a combination relation to feather mass remaining (Y1,%) on the chicken product could be described by Response Surface Regression as following:

$$\mathbf{Y1 = 995.97 - 74.182\ q - 26.831\ T - 1.025\ ts + 13.755\ q2+ 0.189\ T2 + 0.001\ ts2}$$

The confidence limit of equation are "S = 0.0416933" PRESS = 0.110650 R-Sq = 99.99% R-Sq(pred) = 99.92% R-Sq(adj) = 99.98%.

The analysis of variance for Y1,% recorded as shown in table (2) indicated that, all treatments are very high significant effect.

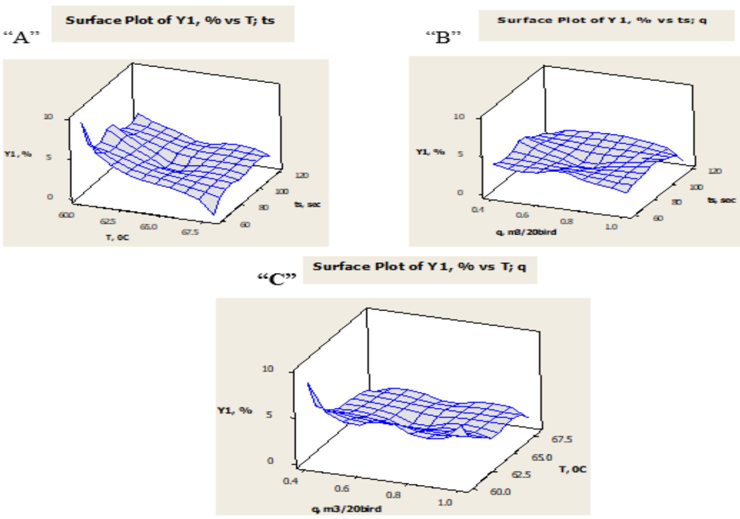


Fig. 2. Factors affecting feather mass remained on chicken (%)

q : scalding water flow (m3/20 bird, means 20 birds conveyed via the scalding equipment at any time);T : scalding temperature, ts: scalding time

Table 2. Analysis of Variance for Y1, %

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	9	136.105	136.105	15.1228	8699.61	0.000
Linear	3	87.154	48.581	16.1937	9315.63	0.000
T, 0C	1	75.461	40.032	40.0323	23029.14	0.000
ts, sec	1	7.547	11.536	11.5365	6636.52	0.000
q, m3/20bird	1	4.147	4.896	4.8958	2816.40	0.000
Square	3	38.272	38.272	12.7574	7338.85	0.000
T,*T,	1	31.208	33.908	33.9080	19506.06	0.000
ts*ts,	1	1.406	1.863	1.8635	1071.99	0.000
q, *q,	1	5.658	5.658	5.6582	3254.97	0.000
Interaction	3	10.679	10.679	3.5596	2047.71	0.000
T, 0C*ts, sec	1	9.828	9.828	9.8282	5653.82	0.000
T, 0C*q,	1	0.828	0.828	0.8281	476.38	0.000
ts, sec*q,	1	0.022	0.022	0.0225	12.94	0.016
Residual Error	5	0.009	0.009	0.0017		
Lack-of-Fit	3	0.007	0.007	0.0022	2.14	0.335
Pure Error	2	0.002	0.002	0.0010		
Total	14	136.114				

De-feathering process

The output data Y2 (feather mass remained on chicken product with the constrained factor of undamaged skin) corresponding to the input parameters (rotating plucking drum "n, rpm"; distance between two de-feathering bands "a, mm" and de-feathering time "td, sec") are illustrate as the surface plot relationship (Fig 3).

Regarding to Figs. 3-A and 3-B, the increasing of "a, mm" lade to increasing Y2 percentage for increasing order of "a mm" from 415 to 485mm, the percentage of " Y2" increased about 15 time. But, the interaction affects between "a, mm" and "n, rpm" more effect than that "a.mm" and "td, s". Also, the interaction between "n, rpm and "td, s", the Fig. 3-C indicated that, by increasing "n, rpm" increased Y2 until maximum point and then falling the amount of "Y2" by increasing "td, s" from 80 to 130s. Under drawing the above variables with response surface effect, the results indicated the rotating plucking drum "n, rpm" possessed the strongest impact on product quality followed by the distance between two de-feathering bands "a, mm" and de-feathering time "td, sec".

For de-feathering process, the influences of de-feathering rotating plucking drum "n" , time "td, s" and distance among two de-feathering bands "a, mm" to percentage of feather mass remained on chicken product can be described by following equation:

$$\mathbf{Y2 = 261.291+0.460\,n-1.276\,a-1.162\,td-0.001\,n2+0.001\,a2+0.001n*a+0.003a*td}$$

The confidence limit of equation is

"S = 0.856650 PRESS = 53.3372 R-Sq = 98.54%

R-Sq(pred) = 78.72% R-Sq(adj) = 95.90%".

The analysis of variance for Y2,% recorded as shown in table (3). Regarding to Figs. 2 and 3 illustrate that the scalding temperature possessed is the strongest influence on product quality followed by scalding time then scalding water flow. It is observed that product quality is in inverse link to scalding temperature. Also, same figures showed that in range of 64 – 68^{0}C of scalding temperature and 0.7 – 1.0 m^3/20 birds of scalding water flow as well as 60 – 120 sec of scalding time then the percentage of feather mass remained becomes on the chicken product after the de-feathering process is less than 2% and undamaged skin.

Table 3. Analysis of Variance for Y2,%

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	9	247.032	247.032	27.4480	37.40	0.000
Linear	3	210.010	21.191	7.0637	9.63	0.016
n, rpm	1	11.329	1.126	1.1264	1.53	0.270
a, mm	1	188.957	9.402	9.4019	12.81	0.016
td,	1	9.724	9.489	9.4886	12.93	0.016
Square	3	11.499	11.499	3.8329	5.22	0.053
n, rpm*n, rpm	1	6.686	5.815	5.8155	7.92	0.037
a, mm*a, mm	1	4.811	4.799	4.7985	6.54	0.051
td,*td,	1	0.002	0.002	0.0023	0.00	0.957
Interaction	3	25.523	25.523	8.5078	11.59	0.011
n, rpm*a, mm	1	3.842	3.842	3.8416	5.23	0.071
n, rpm*td,	1	0.152	0.152	0.1521	0.21	0.668
a, mm*td,	1	21.530	21.530	21.5296	29.34	0.003
Residual Error	5	3.669	3.669	0.7338		
Lack-of-Fit	3	3.279	3.279	1.0929	5.60	0.155
Pure Error	2	0.391	0.391	0.1953		
Total	14	250.701				

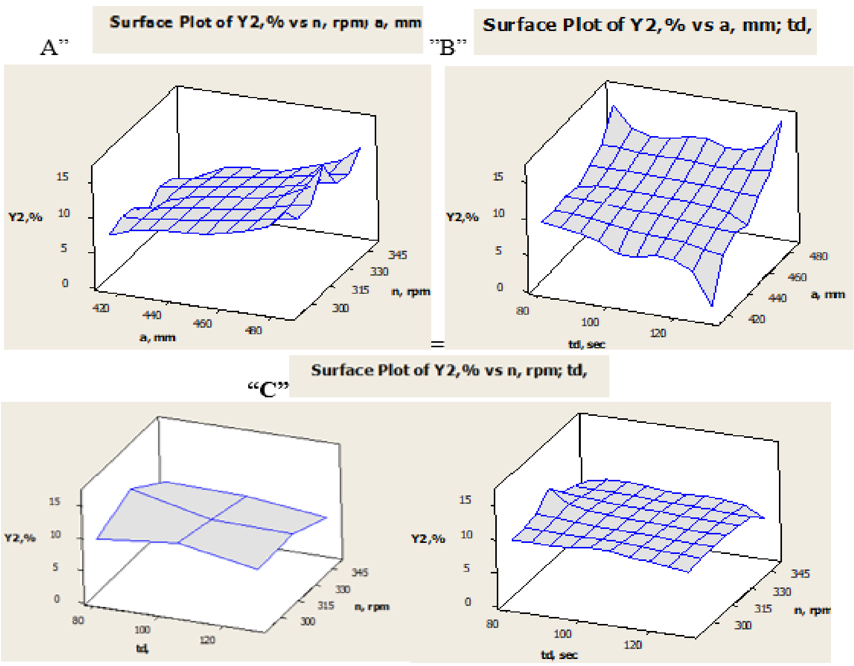


Fig. 3. Factors affecting de-feathering mass remained on chicken (Y2,%)

n: rotating plucking drum, rpm a: distance among two de-feathering bands, mmtd : de-feathering time, s

The same figures showed, the optimized operation parameters where found at: 680C scalding temperature, 0.7 m3/20 birds scalding water flow, 415 mm gap between two de-feathering bands, 90s scalding time for the scalding machine; 105s de-feathering time for the de-feathering machine and 320 rpm de-feathering drum rotation.

Generally, the judgment between Figs. 2 and 3 recommended, the practical assessment for the product quality satisfied under the flowing parameters as shown in table (4).

Table 4. The practical assessment values that recognize satisfied of product equality

Criteria	Appropriate value	Optimized value
Scalding water flow, m^3/20bird	0.7 ±3	0.7
Scalding temperature, ^{0}C	64±4	68
Scalding time, sec	90±30	90
Distance between two de-feathering bands (length of defeathering finger 200mm), mm	450±35	415
De-feathering drum revolution, rpm	320±30	320
De-feathering time, , sec	105±25	105

CONCLUSION

From the obtained results, it can be concluded that the efficiency of scalding process was great compared to that in the de-feathering process. The efficiency of the machine is a function of the rate of removing feathers and time. Generally, the obtained results proved that the constructions of the scalding and de-feathering machines are a so essential innovation for the small scale poultry industry due to it reduces the stress encountered within manual de-feathering. The optimized operation parameters where found at: 680C scalding temperature, 0.7 m3/20 birds scalding water flow, 415 mm gap between two de-feathering bands, 90 sec scalding time for the scalding machine; 105 sec de-feathering time for the de-feathering machine and 320 rpm de-feathering drum rotation.

REFERENCES

Adesan, A and Olukunle, O. J. (2015). Development and Performance Evaluation of a Chicken De-Feathering Machine for Small Scale Farmers. Journal of Advanced Agricultural Technologies Vol, 2(1); 71-74.

Barbut, S. (2002). Primary processing of poultry (Boca Raton London New York Washington, D.C: CRC Press.

Fanatico, A. (2003). Small Scale Poutry Processing. ATTRA.

Hung N.V., Minh D. H., and Son D.T. (2011) An Investigation of Optimized Operational Parameters for a Chicken Slaughtering System in Vietnam. International Transaction Journal of Engineering Management & Applied Sciences & Technologies, 2(4), 423-436.

Jekayinfa, S. O. (2007). Energetic Analysis of Poultry Processing Operations, Leonado Journal of Sciences 10 pp (77-92).

Kiepper, B. H.(2003) Characterization of poultry processing operations, wastewater generation, and wastewater treatment using mail survey and nutrient discharge monitoring methods. MS Thesis. Univ. Georgia, Athens.

OSHA (2004), Occupational Safety and Health Administration. Guidelines for poultry processing; ergonomics for the prevention of muscloskeletal disorders (Washington, D.C.).

تقييم أداء آلة إزالة ريش الدجاج في معالجات الذبح على نطاق صغير

محمد ابراهيم غازي ، زكريا ابراهيم اسماعيل و محمد مصطفي أبو حباجة

قسم الهندسة الزراعية ـكلية الزراعة – جامعة المنصورة.

فرضت متطلبات لحوم الدواجن في مصر مسؤولية كبيرة على صناعة تجهيز الدواجن خاصة في عمليات إزالة الريش. تعد آلات السمط وإزالة الريش ابتكارًا ضروريًا جدًا لصناعة الدواجن على نطاق صغير نظرًا لأنها تقلل من الضغط الذي تواجهه عملية إزالة الريش يدويًا. لذا، فإن الهدف من البحث الحالي هو مناقشة سلوك كفاءة استخدام الطاقة لآلات السمط وإزالة ريش الدجاج في مصر في أنظمة ذبح الدجاج على نطاق صغير. حيث يركز هذا البحث على تحسين كفاءة كل من الآلات والأجهزة المستخدمة في عمليات السمط وإزالة الريش من خلال تقييم المدلولات التشغيلية لتقنيات الآلات المستخدمة وكذلك ترشيد استخدام الطاقة في عمليات الذبح على نطاق صغير. تم تقدير كفاءة استخدام الطاقة في عملية السمط من خلال تحديد الطاقة المتوفرة، المكتسبة من الذبيحة، المخزنة في الماء الساخن والطاقة المفقودة في الفضاء المحيط. بينما تم قياس كفاءة استخدام الطاقة لعملية إزالة الريش حيث كانت آلة إزالة الريش تعمل بسرعات مختلفة لأسطوانة إزالة الريش، (٢٩٠ و٣٢٠ و٣٥٠ دورة في الدقيقة) باستخدام ثلاث فئات لوزن الدجاج تحت درجات حرارة مختلفة (٦٠: ٧٠ درجة مئوية). من ناحية أخرى، تم قياس القوة المطلوبة لإزالة الريش عن الجلد من خلال تجربة تم إعدادها لهذا الغرض.أشارت النتائج إلي أن أفضل قياسات تشغيل تم الوصول إليها عند درجة حرارة سمط ٦٨ درجة مئوية ، و كمية مياه السمط ٠,٧ م٣/ ٢٠ طائر ، والمسافة بين أصابع النزع ٤١٥ مم وذلك في زمن ٩٠ ، ١٠٥ ثانية لكل من السمط ونزع الريش علي التوالى مع سرعة دوران ٣٢٠ لفة / دقيقة.