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Efficient of Energy Use in a Commercial Poultry Slaughterhouse

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ABSTRACT

Seven sequence processing operations were conducted in a private commercial poultry slaughterhouse in order to determine the effects of the variations in the slaughterhouse operation capacity, and in the processed live bird weight, on the energy being consumed, under Egyptian conditions. The energy types used in the processing operations were electrical, gas fuel, and human energy. The respective proportions of these energy forms of the total consumed energy are varied automatically in accordance to the slaughterhouse production capacity. The energy accounting process were proceeded for the specific energy consumption (SEC) in reception, and hanging up; killing and bleeding; scalding; defeathering; evisceration and washing ; chilling ;and packing departments(sections) of the slaughterhouse.The gained results of the present study indicated that:-*Sensible decreases of about 49.4 and 46.4%, in the energy use per kg of poultry product (ready-to-cook), were happened as increasing the slaughter operation capacity from 1000 to 3000 and from 3000 to 6000 respectively. The results also indicated that increasing the average processed live bird weight, from 1.6 to 1.8 Kg and from 1.8 to 2.0 Kg caused reductions in the energy use per kg of product by about 19.7 and 25.3% respectively.* The average specific electrical energy consumptions represents 73.8%, of total specific energy consumption in the investigated slaughterhouse, followed by the average specific thermal energy (gas fuel energy), and human energy which represent 23.43%, and 2.77%, respectively .*Analysis the energy consumption data in the seven defined slaughtering processing operations revealed that the scalding and defeathering are the most consumptive operations, requiring 29.53%, and 36.79% of all energy consumed in processing operations, respectively. Other operations consuming energy in the following order: - Hanging (1.07 %), slaughtering (1.26 %), evisceration (7.91 %), chilling (18.08 %) and packing (5.37 %).

Keywords:-Specific energy consumption, slaughterhouse capacity, Commercial chicken slaughterhouse

INTRODUCTION

The traditional manual methods of chicken slaughtering is gradually going into extinction with the development of different slaughtering processing equipments and machine lines for commercial use. This calls for effective mechanization of the poultry slaughtering process, which achieved a substantial reduction in energy use, support quality, safe operations, ergonomic, and economic slaughtering operations. Therefore, different capacity machines have been developed around the world for poultry slaughtering process, which can handle and processed either very large numbers for commercial, or very few numbers of chickens for household use (Barbut, 2002). The chicken slaughtering equipments (Slaughtering Lines) are manufactured today with different capacities from 1000 birds/h up to sixty thousands birds/h. currently in third world countries, and developing countries, there are large numbers of small size capacity of slaughter processing machines. In contrast the large scale processing slaughtering processing plants are scarcely found (Adesanyaet *et al*., 2015). Following the ban on the importation of poultry products by the Egyptian Government as policy measures to revive the economy and encourage the local poultry industry, there has been an increase in the number of poultry processing slaughterhouses in the country. These areas of poultry business are mostly private owned and supervised by many governmental organizations.

The identified slaughtering processes involved in the production of ready-to-cook poultry are (1) Pre-slaughter: catching and transport; (2) killing, and bleeding, (3) scalding, (4) Feather removal, (5) Removal of head, oil glands, and feet, (6) Evisceration, (7) Chilling, (8) cutting (9) deboning, and further processing, such as packaging, storage and marketing. Among the listed processes scalding and feather removal (defeathering) are the most energy intensive unit operations, most time consuming, less product quality and risky especially when carried out using small capacity machines (Barbut ,2002, Kiepper, 2003 , and Smith,2014).

Many researchers worldwide have studied the energy use efficiency in the poultry production sector (Fritzson and Berntsson, (2006), James *et al*., (2006), Jekayinfa (2007), Marcotte *et al*., 2008, and Heidari *et al*. (2011). They Indicated that, poultry slaughterhouse is an important structure within the poultry production industry, and the amount of energy used in poultry processing in this structure depends on numerous factors; the following are the most frequently mentioned: The structure dimensions, the applied production technology, the manufacturing capacity, (utilization rate, and the throughput volume) ,The processes mechanization degree, Human labour share in the slaughterhouses (the amount of work performed manually). and the thermo-physical properties of the raw material

The up-to-date studies increased their awareness to reduce energy consumption [Wojdalski *et al*. (2009), Heidari *et al*. (2011), and Bueno *et al*. (2015)]. They conducted researches proved that active monitoring is expedient as one of the best techniques of energy management in conjunction with the current production volume. They reported that from the point of view of selection of a specified technology, it is important to use a coefficient that would comprise the total energy consumption in the processing slaughter. For this end, the specific energy consumption (SEC) indicator is adopted. It is denoted as energy consumed (kJ) per one kg of production. Bueno *et al*. (2015) reported that in poultry slaughterhouses that have a large production scale, the specific consumption may influence significantly the final cost. This indicator (SEC), which is the energy consumption per product, is important and can be used as an indicator of energy use and may indicate the need of implementation of energy conservation measurements.

It is notable that the poultry industrial sectors have deficiency in electric energy use. According Oliveira and Rabi (2005), the lower (SEC) indicator the lower the cost of energy used and more appropriate and rational is the use of electricity. Studies carried out by IFC World Bank Group, (2007) indicated that that the total electrical energy consumption per manufactured unit in EU poultry plants amounted to 0.152 – 0.86 KW.h/kg of the slaughtered poultry volume. A similar results were obtained by Garcia *et al*. (2007), and Bueno and Sarubbi *et al*. (2008) which showed that the (SEC), in a slaughterhouse processes, was of 0.15 kWh kg of chicken meat.

Jekayinfa, (2007) conducted energy audit of three poultry processing plants in southwestern Nigeria. He grouped the slaughtering plants into three different categories based on their production capacities. The energy survey involved all the five easily defined unit operations utilized by the poultry processing industry and the experimental design allowed the energy consumed in each unit operation to be measured. The results of the audit revealed that scalding & defeathering is the most energy intensive unit operation in all the three plant categories, averagely accounting for about 44% of the total energy consumption in the processing plants. Other processing operations consuming energy in the following order are eviscerating (17.5%), slaughtering (17%), washing & chilling (16%) and packing (6%).

Yi Liang, *et al* (2014) showed that, the type and magnitude of the energy consumed is a function of the technology employed and the number of birds being processed. In order to quantify the energy demands of each unit operation, quantitative data on operating conditions would be required for each unit operation.

In fact most of the owners and managers of the poultry slaughterhouses have no precise idea about the energy consumption variations due to processing different production capacities in the same slaughterhouse area. In additions, there are no scientific literatures on the energy consumption and requirements of different poultry processing operations as practiced in poultry slaughterhouses under the Egyptian conditions. Energy analysis allows the energy cost of existing process operations to be compared with that of new or modified slaughtering lines. It also enables a plant operator to compare his energy efficiency with that of a competitor or with that of another factory within the same company. Therefore, the present study aims to estimate proportions of energy consumption in the main seven defined poultry processing operations as practiced in Egypt. The study will provide an opportunity for having a reliable database concerning consumption of various types of energy and will also provide a firm basis of identifying options for saving energy in poultry process operations. Whereas, the main emphases of the present study are on the following objectives:-

- ❖Quantifying the total energy consumption in slaughterhouse as affected by the variations in the slaughterhouse operation capacity, and in the processed live bird weight
- ❖Identifying the contribution of the utilized energy sources, and determine the main energy consuming process in slaughterhouses
- ❖Estimating the energy efficiency indicators for benchmarking purposes
- ❖Applying linear regression analysis to relate the amount of poultry product (ready-to-cook), with the energy consumption items

MATERIALS AND METHODS

Data of the energy consumption pattern used in this research work was obtained from a private commercial poultry slaughterhouse, specialized in poultry meat products in Elsanta city, Al-Garbia Governorate, Egypt. It is under the inspection of the Egyptian Ministries of health and agriculture.

1-The slaughterhouse description

The slaughterhouse selected for the present study represents the processing techniques and facilities of Meyn Company. The employed slaughtering machine employed in that slaughterhouse were manufactured, imported, and installed under the supervision of Meyn specialists.

The employed slaughtering machine lines are manufactured with different production capacities. The studied slaughterhouse has the potential to process from about ten to sixty thousands of chickens a day. Its production capacity characteristics are as follows:

Small size capacity: the slaughterhouse is processed at a rate of 1000 chicken per hour.

Medium size capacity: the slaughterhouse is processed at a rate of 3000 chicken per hour.

Large size capacity: the slaughterhouse is processed at a rate of 6000 chicken per hour.

In the investigated slaughterhouse a number of processing equipment (machines) are mechanically driven by the overhead conveyors through different geared electric motors as illustrated in table (1). Hence the electric energy consumption for each process depends on the number and the power of motors used on each overhead conveyor line.

Meanwhile, the parameters required for generating energy input in investigated poultry processing slaughter were monitored for each studied operation capacity and process as illustrated in table (1)

Table 1. Parameters required for generating energy input in investigated slaughterhouse

No.	Operation	Required parameters	Magnitudes of the parameters required		
			Small capacity	Medium capacity	Large capacity
1	Hanging up	Electrical motor power, kW	0.64	0.64	0.64
		Number of labors involved	2	3	4
2	Slaughtering	Electrical motor power, kW	0.896	0.896	1.088
		Number of labors involved	2	3	4
3	Scalding	Electrical motor power, kW	2.816	2..816	5.632
		Gas fuel consumed, L	16	27	44
		Number of labors involved	1	1	1
4	Defeathering	Electrical motor power, Kw	14.53	14.53	28.352
		Number of labors involved	1	1	2
5	Eviscerating	Electrical motor power, kW	8.586	8.586	8.5856
		Number of labors involved	16	16	28
6	Washing and chilling	Electrical motor power, kW	5.596	5.596	9.856
		Number of labors involved	5	5	8
		Electrical consumed power, kW	8.5	9.4	18.3
7	Packaging	Electrical motor power, kW	6.592	6.592	6.592
		Number of labors involved	20	20	30

2-Processing technology

The slaughtering machinery lines involve seven sequence processing operation units namely:-

1) Hanging, 2) Killing and Bleed out, 3) Scalding, 4) Defeathering, and washing 5) Evisceration, 6) Chilling, and 7) Packaging (ready-to-cook product). The flow diagram of these processing operations is outlined in Figure (1).

The common processing steps used for slaughtering different production capacity, with different processed live bird weight, may be described as follows:-

The cages containing different live bird categories are offloaded, and placed on a conveyor belt and directed to towards the "infinite" conveyer, where it is hung with heads down. Live birds are then slaughtered manually by the outside cut on the ventral part of throat, where throat arteries and veins are cut. Time of bleeding is about 2 minutes and the length of flume is adjusted to it. Flume traps 50 -70 % of all blood, which represents 7 - 10 % of live bird mass. The blood is pumped into the tanks of processing slaughter and is used for the production of feed.

Bleeded birds are then steamed in a steam scalder in the temperature of 60°C for 50 -120 seconds. Steaming water gets to the skin by moving both steamed poultry and also water in flumes. Steamed poultry is plucked within 15 minutes after steaming on special plucking machines without being removed from the hanging device. Feather is washed off through self-cleaning racks into a container.

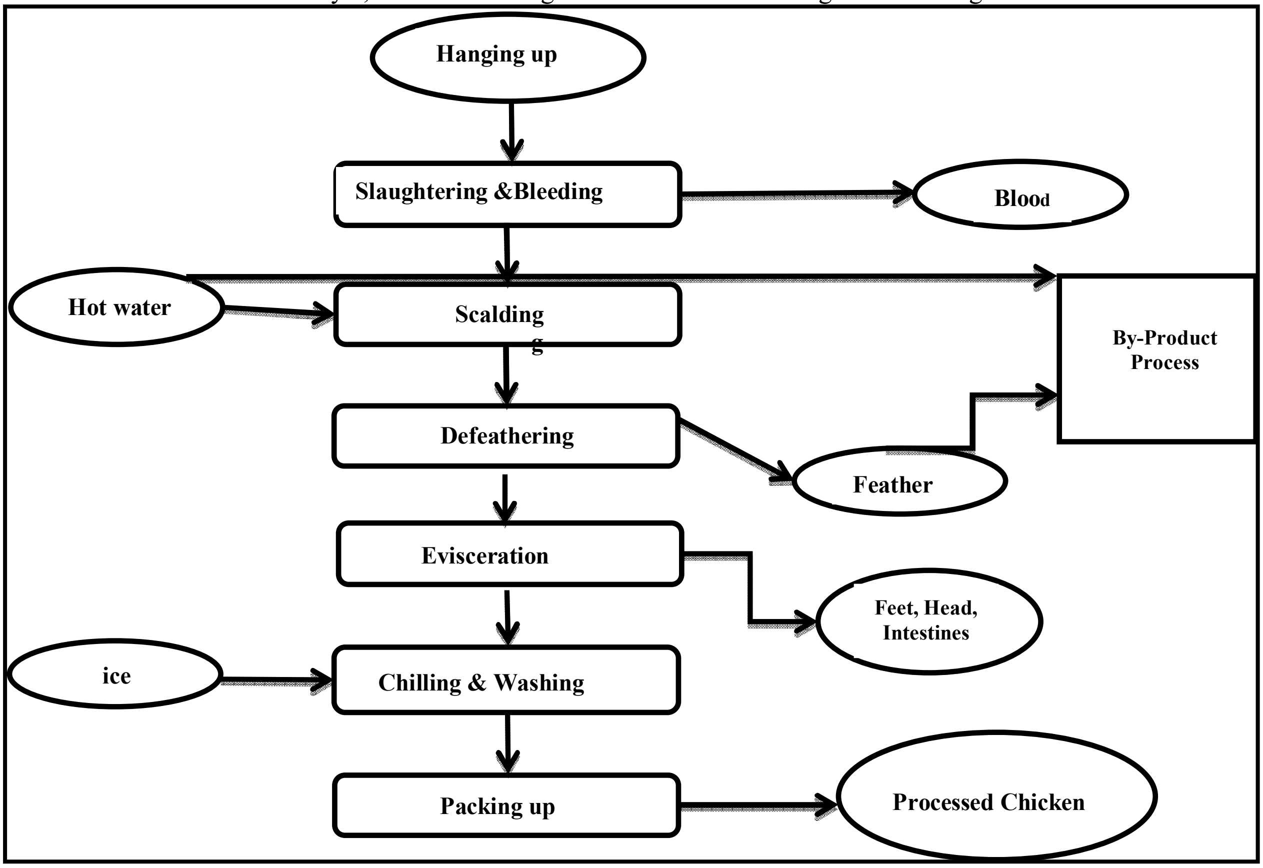


Figure 1. The flow diagram of the poultry processing operations

Edible entrails (livers, heart, and maw) are then separated manually from non-edible ones. Non-edible entrails are splashed onto a separator and taken into a container. During drawing poultry is constantly washed by water.

Edible entrails (livers, heart, and maw) and throats are cleaned and processed individually. After that they are packed for sale or put into the body of cooled poultry. Automatic machine is used for cleaning muscled stomachs. Muscles are separated from internal contents (sand, stones), which are splashed together with bowels into a settling tank. Drawn poultry have to be cooled to the temperature of 6 - 10 °C in order to stay conserved.

3-Experimental procedure

Upon the arrival at the slaughterhouse, birds were grouped into three different categories based on their weight namely:-1500:1700; 1700-1900; and 1900-2100 gr.. Then the slaughtering machine lines were adapted to process at the selected production capacities. However, birds were weighed individually and sorted and categorized according to their weight, categories. The selection and weight measurement of live birds was repeated until the number of birds in a mass range reached 1000 birds. Five batches each of 200 birds represent each bird weight categories whereas, 200 birds randomized samples from each sorted weight category were counted and its birds are placed in special crates in the reception area to be put on the killing line.

4-Energy analysis procedures

The energy analysis methodology consisted of two different stages: - Firstly stage, was specified for quantifying the amounts of energy consumption by each energy source and each processing operation used in the slaughterhouse. The energy inputs include electricity; human labor; and gas fuel. Second stage was used to estimate energy efficiency indicator (Specific Energy

Consumption, SEC), which is denoted as energy consumed (KJ) per one Kg of the slaughtered poultry volume (ready to cook carcasses).Finally, regression equations were derived to relate the specific energy consumption, SEC values to the values of the three used energy forms and total energy consumption.

The measurements of the first procedure stage embraced processing of 9000 live birds divided into forty five batches each of 200 birds with three specified live bird weight categories, for which necessary energy data sets were obtained.

The measurements of the second procedure stage involved also processing of 9000 live birds, but they divided into 9 batches only each of 1000 birds. The stage was specified for quantifying the slaughtered poultry volume (ready to cook carcasses) that produced from each of the nine deduced treatments (3 operation capacities × 3 bird weight categories).

In the present study, SPSS 15 spreadsheets, were used, whereas, the energy equivalents of the energy inputs and output ready-to-cook production, were entered to calculate the specific energy equivalents. Consequently linear regression analysis was applied to derive the necessary regression equations as used by previous researchers (Singh *et al*., 2002). The application of the obtained regression equations allowing for correlation (r) and determination coefficients (R2) enables partial explanation of the energy efficiency under discussion in the deduced chicken slaughter.

5.Measurements:

To fulfill the objectives of this study, the measured and computed quantities required in each of the nine deduced treatments (3 operation capacities × 3 bird weight categories),were as follows;-

Actual Processing Time

The actual expenditure time spend for processing 1000 birds through the seven defined slaughtering operations under different slaughterhouse operation capacities were measured and recorded for each processed live bird batch (200 birds),in each of the nine deduced treatments (3 operation capacities × 3 bird weight categories).

Electric Energy consumption:

Generally most of processing machines are mechanically driven by the overhead conveyors through different geared electric motors in a specific time. Hence the electric energy consumption for each process depends on the number and the power of motors used in each overhead conveyor line as illustrated in table (1).

Electric energy consumed by each motor was calculated through measuring the line current strength clamp meter and the potential difference values. The following formula was used to estimate the electricity consumption (kWh)

$$Ee = \sqrt{3} * I x\ V\ x\ T\ x\ (PF)\ x\ (cf)$$

Where:

Ee = electrical energy consumption, kJ

√ 3 = coefficient current of three phase.

I = line current strength, ampere.

V = potential difference, voltage.

T = time taken for the operation, h.

(PF) = power factor of motor as obtained from the capacitor monitor.

(Cf) = conversion factor (to account for the inefficiency of electrical power

Gas fuel energy consumption:

The measurements of gas fuel consumption were carried for the nine deduced treatments with five batches replicates at each investigated treatment. These measurements were done using a gas fuel flow meter, which was installed in scalding season that was used in scalding process.

Quantity of fuel consumed in each investigated treatment was converted into equivalent energy (kJ) using appropriate coefficient One liter of Gas fuel oil = 54.600 kJ/liter [Reference Ministry of Supply and Home Trade.].

Human energy consumption

According to Megbowon, and Adewunmi, 2002; Jekayinfa and Olajide (2007) at the maximum continuous energy consumption rate of 0.30 kw and conversion efficiency of 25 percent, the physical power output of a normal human labour in tropical climates is approximately 0.075 kw sustained for an 8-10 h workday. However the number of workers in any process is different depending on the processing capacity as shown in table (1).Hence, the Human energy expenditure in an operation was quantified by multiplying the number of persons engaged in unit operation by the man-hour requirement and energy equivalent for human power.

The specific energy consumption (SEC)

The total SEC is defined as the ratio of the total amounts of energy being consumed in the slaughterhouse (KJ) to the slaughterhouse output volume (ready to cook carcasses mass, kg).. This indicator was calculated for each of the nine investigated treatments using the following equation:

$$SEC_I = CA / QP$$

Where:

SEC_I =the total specific consumption (kJ. kg^{-1}),

CA - Total treatment average of energy consumption in kJ, and

QP – Total treatment average chicken meat produced in the slaughterhouse in kg

The energy equivalent conversion factor, (1kW.hour = 3.6MJ =3600KJ).

In addition the specific energy consumption (SEC), values for each of the three used energy forms (electrical, gas fuel, and human energy) were determined in the slaughterhouse in order to discuss the changes in different used energy-efficiency as affecting by of the slaughterhouse capacity, and the processed live bird weight factors. For example, the specific energy consumption for electricity was calculated using the following Equation;-

$$SEC_E = QE / QP$$

Where

SEC_E = the specific electrical energy consumption ((kJ. kg^{-1}),

QE = the electricity consumption (kJ), and

QP = average chicken meat produced in the slaughterhouse in kg

RESULTS AND DISCUSSION

Gathered data was analyzed in order to determine each of the following:- the total energy ,consumption profiles in slaughterhouse as affected by the variations in the slaughterhouse operation capacity, and in the processed live bird weight , the contribution of the three energy sources and the main energy consuming processes in slaughterhouses, the energy efficiency indicator(SEC). and regression equations relating the, SEC to the of the three used energy forms and total energy consumption. Therefore, the obtained results of the present study could be discussed under the following headings:

1. Energy consumption profiles

Inspection of the data showed in table (2) it can be seen that increasing (BPH) from 1000 to 3000 and from 3000 to 6000 (BPH) resulted in reducing in average total energy consumption values by about 49.4 and 46.4% .While increasing the processed average live bird weight (LBW), from 1.6 to 1.8 Kg and from 1.8 to 2.0 Kg exhibited SEC reduction by about 19.7 and 25.3% respectively.

Table 2. shows the energy consumption profiles in slaughterhouse as affected by the variations of the slaughterhouse operation capacity, and the processed live bird weight.

Experiment Teratments		Experimentatal Measurments							
		The contributions of different energy source, (MJ), and% of the total						Total energy consumption.	
Process Capacity	Processed Live bird mass	Electrical energy		Human Energy		Fuel energy			
(BPH)		(MJ)	%	(MJ)	%	(MJ)	%	(MJ)	KW.h
Small capacity (1000)	$(LBW)_1$	41.738	72.7	1.3284	2.3	14.36	25	57.426	15.952
	$(LBW)_2$	43.346	73.4	1.3284	2.3	14.36	24.3	59.034	16.398
	$(LBW)_3$	44.520	73.9	1.3284	2.2	14.36	23.9	60.208	16.724
AVG		43.201	73.3	1.3284	2.3	14.36	24.4	58.889	16.358
Medium capacity (3000)	$(LBW)_1$	65.049	73	2.5542	2.9	21.54	24.2	89.143	24.762
	$(LBW)_2$	67.651	73.7	2.5542	2.8	21.54	23.5	91.745	25.485
	$(LBW)_3$	69.356	74.2	2.5542	2.7	21.54	23	93.45	25.958
AVG		67.352	73.7	2.5542	2.8	21.54	23.6	91.446	25.402
Large capacity (6000)	(LBW)1	138.252	73.7	6.237	3.3	43.08	23	187.569	52.103
	(LBW)2	144.233	74.5	6.237	3.2	43.08	22.3	193.55	53.764
	(LBW)3	147.91	75	6.237	3.2	43.08	21.8	197.227	54.785
AVG		143.465	74.4	6.237	3.2	43.08	22.4	192.782	53.551

From table (2), it can be also noticed that there is no significant differences of the respective proportions of different energy source as the slaughter operation capacity or the processed average live bird weight were varied. However it can be stated that the average electrical energy consumptions represents 73.8%, of total energy consumption in the investigated slaughterhouse, followed by the average thermal energy (gas fuel energy), and human energy which represent 23.43%, and 2.77%, respectively

Fig (2) shows the average total energy accounting (MJ) diagrams in the investigated slaughterhouse as the slaughterhouse operation capacity was varied. While, Fig (3) identifies effects of the processed live bird weight on total energy consumption

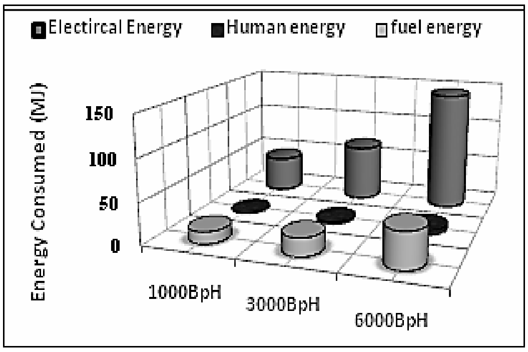


Fig. 2. effects of the slaughterhouse operation capacity on the total energy consumption

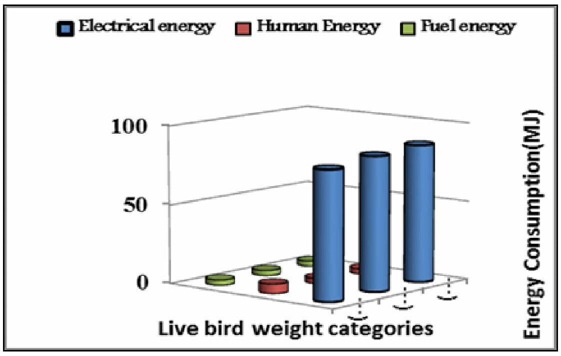
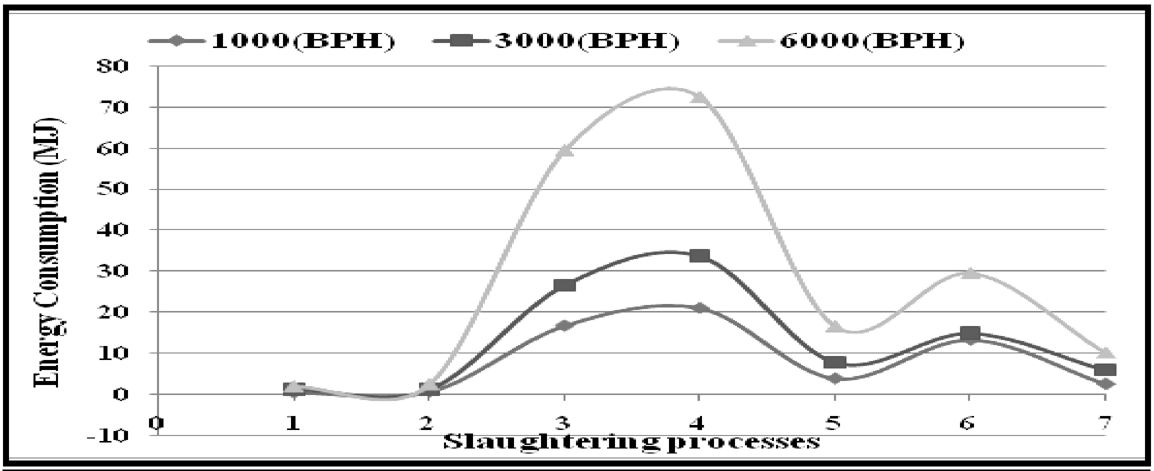


Fig. 3. effects of the processed live bird weight on total energy consumption

The results of the energy audit, in the investigated slaughter clearly indicated that the large capacity of the slaughter consumed the highest energy192.78MJ (53.551 KW.h) followed by the medium capacity which consumed 91.446 MJ (25.402 KW.h) and the small capacity consumed 58.889MJ (16.358KW.h),

2-The distribution of total energy inputs

The energy consumption of all equipment involved in the seven slaughter process was measured for each treatment. The distribution of the total energy consumption in (MJ) at the seven sequence processing operations in the poultry slaughter as affected by the different investigated slaughterhouse capacities was estimated in (KW.h). Then considering the energy equivalent conversion factor, 1kW/hour = 3.6MJ, the contributions and fluctuations of energy consumption (MJ) in each of the seven sequence slaughtering process as affected by the slaughterhouse capacity (BPH) are shown in fig (4).



(1) Hanging up (2) killing, and bleeding (3) Scalding (4) Defeathering (5) Evisceration (6) Chilling (7) Packaging

Fig. 4. Fluctuations of energy consumption in each slaughtering process as affected by the slaughterhouse capacity

From fig (4) clearly indicated that the energy consumed in both scalding and defeathering operations were 18.74, 28.29, and 60.41MJ as the slaughterhouse was operated at operation capacities of 1000, 3000, and 6000 BPH respectively. it can be stated that ,the most energy was consumed in the defeathering operations (36.8%) followed by scalding operations (29.5%) of the total energy consumption in the investigated slaughter. Other processing operations consumed energy as follows eviscerating &washing (7.91%), slaughtering (1.26%), Hanging (1.06%), chilling (18.09%) and packing (5.36%). However, from fig (4) it can be seen that there are a clear fluctuation of energy consumption rates in each slaughtering process was observed as (BPH) was varied. The results of the energy consumption revealed that decreasing the slaughterhouse capacity by about 83% (from 6000 to 1000 BPH), resulted in decreasing the amounts of energy consumptions by only about 75.1;72.1; 71.8; 70.9; 76.5;54.9, and74.5% respectively in processing operations Hanging; Killing and Bleed out; Scalding; Defeathering and washing ; Evisceration; Chilling, and; Packaging. In general the total energy consumption, for accomplishing the seven sequence processing operations was increase by about 227% as the slaughterhouse capacity was increased from 1000 to 6000 BPH.

3- The specific energy consumption (S.E.C)

The obtained data corresponds to processing 1000 birds in each investigated treatments are shown in table (3) . The obtained data include ;- the total processed live bird mass, the average produced ready-to-cook carcass mass, and the average total energy consumption, for each investigated treatments. Consequently, the total (SECI) specific consumption (kJ. kg-1), could be determined for each treatment, and plotted in the same table (3).

Table 3. Average (SEC) vales for processing 1000 birds under different operation capacities and live bird weights

Slaughter operation Capacities	Live bird weight categories	Average ready-to-cook carcass weights (Kg)	Average of total Energy consumption		(SEC)
			(MJ)	KW.h	(Kj/Kg_{clean})
	$(LBW)_1$	1065.43	57.43	15.95	53.90
Small capacity	$(LBW)_2$	1378.50	59.03	16.40	42.82
	$(LBW)_3$	1503.53	60.21	16.72	40.04
AVG		1315.82	58.89	16.36	44.75
	$(LBW)_1$	1121.10	31.26	8.68	27.88
Medium capacity	$(LBW)_2$	1381.29	32.26	8.96	23.35
	$(LBW)_3$	1518.63	32.87	9.13	21.65
AVG		1340.34	32.13	8.93	23.97
	$(LBW)_1$	1076.93	29.71	8.25	27.59
Large capacity	$(LBW)_2$	1412.87	30.58	8.50	21.65
	$(LBW)_3$	1555.37	31.15	8.65	20.03
AVG		1348.39	30.48	8.47	22.61

The estimated specific energy consumption(SEC) show mean values of about 44.75, 23.97 ,and 22.61 Kj/Kgclean, corresponds to the small capacity, the medium, and the large operation capacity respectively. These (SEC) values exhibit distinct reduction as the slaughter operation capacity was increased from 1000 to either 3000 or 6000 birds/hr.

Concerning, the variations in (SEC) values due to the variations in processed live bird weight, the obtained results indicated also that the (SEC) values exhibit clear reduction as the average live bird weight was increased from 1.6 to either 1.8 or 2.0 kg.

From the data shown in table (3), and illustrated above, it can be stated that the energy use efficiency in the studied slaughterhouse, exhibits a higher increasing fluctuation as its operation capacity is increased from 1000 to up either 3000 birds/hr. in addition the slaughterhouse energy use efficiency exhibits a small increasing as processed live bird weight is increased up to 2.0 kg.

On the other hand, the specific energy consumption, SEC values representing the three used energy forms and its proportions to the total energy consumption were estimated corresponding to each operation capacity. The obtained data are listed in tables (4, 5, and 6).

The listed data in tables (4, 5, and 6) show differences between the energy use efficiency (SEC, values), concerning the energy electrical sources especially in the defeathering, and chilling operation. Whereas, SECE, values in the defeathering, operation were 15.99, 8.32, and 8.99 and in chilling operation were 9.96, 3.59, and 3.62 under slaughterhouse operation capacities of 1000, 3000, and 6000 bird/hr, respectively. The SECE, values distributed in operation sectors are almost similar in both operation capacities of 3000, and 6000 bird/hr. Also, the SEC, values concerning the Gas fuel source (thermal energy) is almost similar in both operation capacities of 3000, and 6000 bird/hr. the above mentioned result trend may be due the coinciding of the machinery line constructions , used in both processing capacities of 3000, and 6000 bird/hr. the average specific human energy consumption, presented in tables (4, 5, and 6) were, 1.01, 0.63 and 0.78 KJ/Kg under slaughterhouse operation capacities of 1000, 3000, and 6000 bird/hr, respectively.

Table 4. The (S.E.C) of each energy type at processing operation capacity of 1000BPH

Process(1000BPH)	S.E.C (KJ/Kg)			Total KJ/ Kg	% of Total
	Electrical	Human	Gas Fuel		
Hanging up	0.30	0.06	---	0.37	0.83
Slaughtering and Bleeding	0.45	0.07	---	0.52	1.16
Scalding	1.80	0.03	10.91	12.75	28.49
Defeathering	15.99	0.06	---	16.05	35.86
Evisceration	2.64	0.33	---	2.97	6.64
washing and Chilling	9.96	0.18	---	10.14	22.65
Packing up	1.67	0.29	---	1.96	4.38
Total(KJ/Kg)	32.82	1.01	10.91	44.76	100

Table 5. The (S.E.C) of each energy type at operation of capacity 3000BPH

Process (3000BPH)	S.E.C (KJ/Kg)			Total KJ/Kg	% of Total
	Electrical	Human	Gas Fuel		
Hanging up	0.25	0.06	---	0.31	1.37
Slaughtering and Bleeding	0.25	0.06	---	0.31	1.37
Scalding	1.25	0.02	5.32	6.60	29.19
Defeathering	8.32	0.03	---	8.34	36.89
Evisceration	1.74	0.18	---	1.92	8.49
washing and Chilling	3.59	0.09	---	3.67	16.23
Packing up	1.26	0.20	---	1.46	6.46
Total	16.65	0.63	5.32	22.61	100

The obtained results clearly indicated that the, the maximum SEC, value (53.9 kj/kg)) was recorded at slaughter processing capacity of 1000BPH as producing an average clean bird weight of 1.11kg .While the SEC average values of (20.02, and 21.6 kj/kg) have been estimated at slaughter processing capacity of 3000, 6000BPH as producing an average clean bird weight of 1.4, 1.5 kg respectively..

Table 6. The (S.E.C) of each energy type at operation capacity of 6000BPH

Process (6000BPH)	S.E.C (KJ/Kg)			Total KJ/Kg	% of Total
	Electrical	Human	Gas Fuel		
Hanging up	0.18	0.06	---	0.24	1.00
Slaughtering and Bleeding	0.25	0.06	---	0.30	1.25
Scalding	2.03	0.01	5.36	7.41	30.91
Defeathering	8.99	0.03	---	9.02	37.63
Evisceration	1.74	0.33	---	2.06	8.59
washing and Chilling	3.62	0.06	---	3.68	15.35
Packing up	1.03	0.23	---	1.26	5.26
Total	17.84	0.78	5.36	23.97	100

As a result of analysis energy consumption audit the present investigation it could be came to a conclusion that SEC were reduced by 19.7%,25.3%as the slaughter capacity is increased from 3000BPH to 6000BPH receptivity; under the same poultry slaughtering condition.

Putting in mind that the lower (SEC) indicator the lower cost of energy used and more appropriate and rational is the use of energy, consequently, it is notable that the investigated poultry slaughterhouse has deficiency in electric energy use, especially in the defeathering and chilling operations. Other process do not constitute a significant fraction of the energy used

4- The developed regression equations

The estimated data of specific energy consumption were subjected to the statistical analysis method, whereas, the fit regression curves are shown in figures (from 5to 10). In addition the fitted linear regression equations expressing variability of energy were obtained, and presented in tables (7and 8).It was taken into consideration that the derived regression equations should be separately developed for electrical energy ,human energy, and for thermal energy.(as in the works done by Rao [1986], Singh [1986], and Hackett *et al.* [2005].

However, the regression equations fitted the relations between slaughter capacity and the specific energy consumption of each used energy source is listed in table (7). While, obtained regression equations fitted the relations between slaughter capacity and the processed live bird weight is listed in table (8).

On the ground of the regression analyses conducted, tables (7and 8) includes empirical equations expressing the impact of slaughtering capacity and live bird weight factors on the specific energy consumption

The obtained empirical formulas may be useful for forecasting electrical and thermal energy consumption in order to define standards of the best available techniques for accomplishing the seven sequences deduced processing operations.

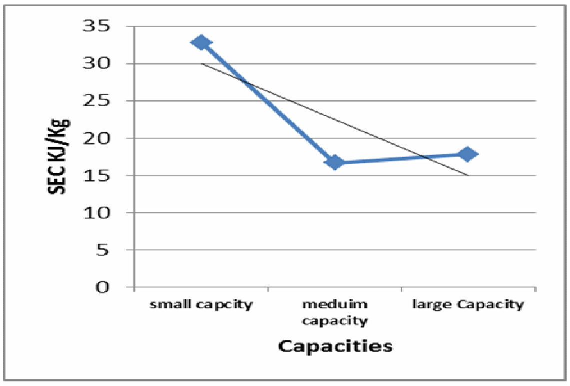


Fig. 5. Relationship between slaughter capacity and specific electrical energy consumption

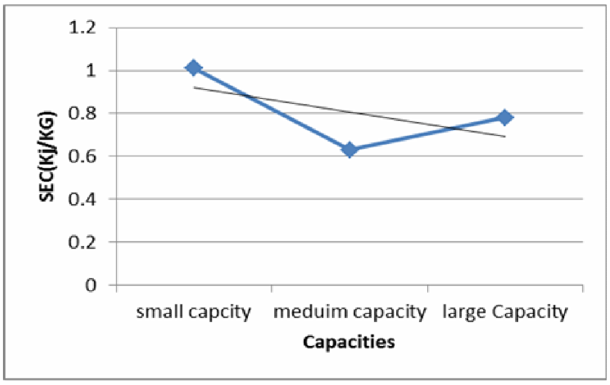


Fig. 6. Relationship between slaughter capacity and specific human energy consumption

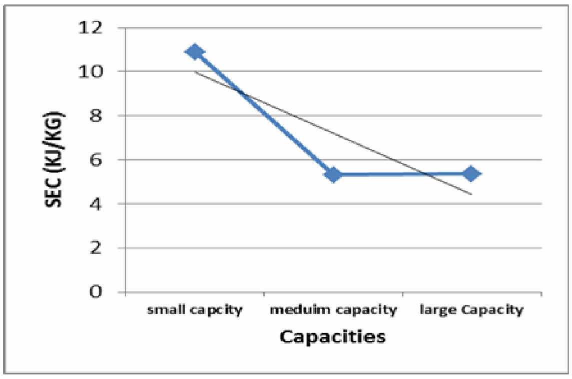


Fig. 7. Relationship between slaughtering capacity and specific thermal energy consumption

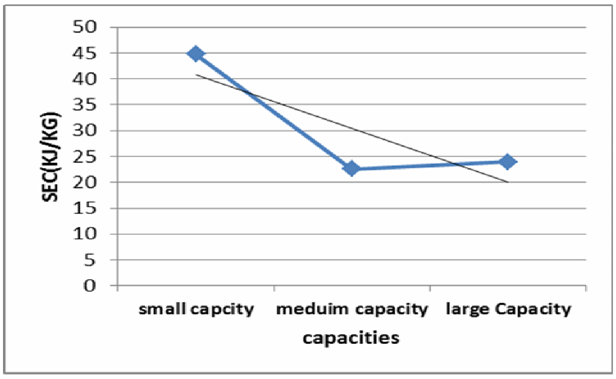


Fig. 8. Relationship between slaughtering capacity and total specific energy consumption

Table7. The relationship between slaughtered poultry mass (Kg), and the specific consumption of energy forms

Item	Regression equations	r (R^2)	Symbols
1	$E_{elc} = -7.49x + 37.417$	0.831(0.6908)	E_{elc}= specific electrical *energy consumption [kj/Kgcleanbird]* *X= [*Slaughter poultry mass,Kg*]*
2	$E_{HU=}-0.115x + 1.0367$	0.601(0.361)	E_{HU} = specific human energy consumption[*kj/Kgcleanbird]*] *X= [*Slaughter poultry mass,Kg*]*
3	$E_{FU} = -2.775x + 12.747$	0.863(0.7446)	E_{FU} =specific fuel energy consumption [*kj/Kgcleanbird]*] *X= [Capacities,(BPH)]*
4	$E_T = -10.395x + 51.237$	0.837(0.7011)	E_T= [Total specificl energy consumption *kj/Kgcleanbird*] *X= [Capacities,(BPH)]*

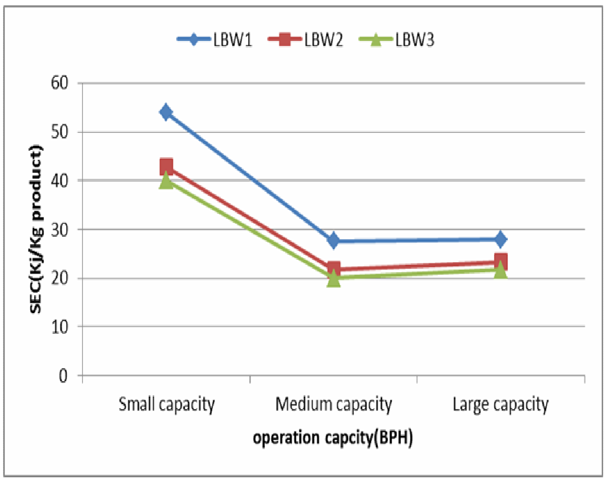


Fig. 9. The relationship between SEC and operation capacities under different processed live bird weights

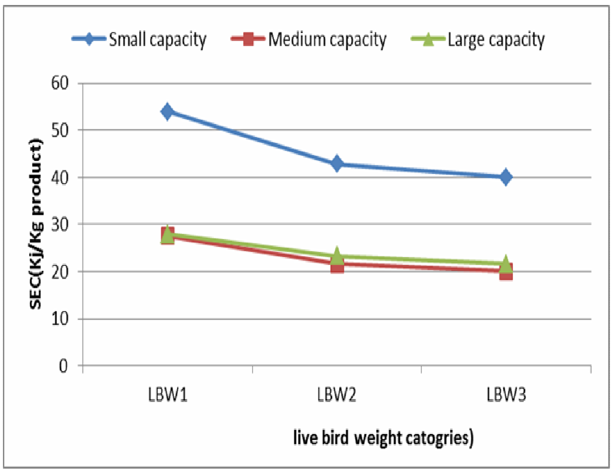


Fig. 10. The effects of live bird weight on SEC under different operation capacities

On the ground of the analyses conducted, Table (7-9) includes empirical formulas expressing the impact of factors comprised in the four adopted groups on electrical energy consumption.

The formulas obtained explain to a high degree the reasons for the variability of daily electrical energy consumption and coefficients of electrical energy consumption per unit of output. They allow the analysis the variability of electrical energy consumption while taking into account relevant technical, technological, and other factors.

Table 8. The relationship between operation capcities (BPH), and the specific consumption of energy

Item	Regression equations	r (R^2)	Symbols
1	Y1 = -13.01x + 62.477	0.861 (0.7416)	Y1= specific *energy consumption at small capacitiy [kj/Kgclean bird]* *X*= *[*Slaughter poultry mass(ready to cock) ,Kg*]*
2	Y2 = -9.735x + 48.743	0.828 (0.685)	Y2= specific *energy consumption at small capacitiy* [*kj/Kgcleanbird]*] *X*= *[*Slaughter poultry mass,(ready to cock) Kg*]*
3	Y3 = -9.195x + 45.63	0.827 (0.6844)	Y3 = specific *energy consumption at small capacitiy* [*kj/Kgcleanbird]*] *X*= *[*Slaughter poultry mass,(ready to cock) Kg*)]*

Table 9. The relationship between live bird weight categories,and the specific consumption of energy.

Item	Regression equations	r (R^2)	Symbols
1	y = -6.93x + 59.447	0.945 (0.8932)	Y1= specific *energy consumption at small capacitiy [kj/Kgclean bird]* *X*= *[*Slaughter poultry mass(ready to cock) ,Kg*]*
2	y = -3.78x + 30.65	0.949 (0.9018)	Y2= specific *energy consumption at small capacitiy* [*kj/Kgcleanbird]*] *X*= *[*Slaughter poultry mass,(ready to cock) Kg*]*
3	y = -3.115x + 30.523	0.967 (0.9356)	Y3 = specific *energy consumption at small capacitiy* [*kj/Kgcleanbird]*] *X*= *[*Slaughter poultry mass,(ready to cock) Kg*)]*

A prominent negative correlation between SEC and carcass production was found especially in slaughterhouse

CONCLUSION

The Egyptian poultry industry sector is strongly dependent on the economics poultry meat production which can benefit from a better energy management throughout the whole poultry meat production chain, including the slaughtering processing operations. Therefore, in this study, energy consumptions for seven sequence slaughtering processing operations were investigated in a private commercial poultry slaughterhouse. The energy surveys and energy audits performed in this study allowed for indentifying the energy consumption profiles in the slaughterhouse. The obtained results showed a relevant potential margin for improving energy efficiency and lowering costs in most poultry slaughterhouses in Egypt. The research conducted leads to the following conclusions:

1. The total energy accounted amounts, that were consumed for accomplishing the operation from hanging up to packing process, were estimated to be about 16.358; 25.402; and53.551 KW.h (58.889; 91.446; and192.782 MJ) for processing slaughter capacities of about 1000,3000,6000 birds per hour respectively.
2. The most energy intensive unit operations were the scalding and defeathering departments. They are averagely accounting was about 66.3% of the total energy consumption in the investigated slaughter.
3. Electricity is the most used energy source in the slaughterhouses with a contribution of around 73.8 %, of total specific energy consumption in the investigated slaughterhouse. Natural gas (thermal energy), in slaughterhouse used for heating scalding water take the second place, with a mean contribution of about 23.43%. While the third contribution of 2.77% was generated by human labour, which is essentially used in all processing.
4. Analysis specific energy consumption audit, revealed that, increasing (BPH) from 1000 to 3000 and from 3000 to 6000 (BPH) resulted in reducing in SEC values by about 49.4 and 46.4% .While increasing LBW from 1.6 to 1.8 Kg ;and from 1.8 to 2.0 Kg exhibited SEC reduction by about 19.7 and 25.3% respectively.

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كفاءة استخدام الطاقة في مجزر دواجن تجاري

على السيد ابوالمجد ، ياسر مختار صالح الحديدى و محمد عبد الحميد محمد عبد الحميد
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الهدف الرئيسى من هذا البحث هو تحديد مدى فعالية إدارة الطاقة في المجازر الالية لتجهيز لحوم الدجاج، إلى جانب ذلك يهدف البحث الى اشتقاق معادلات الانحدار التي تربط انتاجية المجزر مع استهلاك الطاقة والمفيدة لمستخدمي الطاقة في مجازر الدواجن خاصة عند تشغيل المجزر على سعات انتاجية واوزن طيور حية مختلفة. وقد حددت كفاءة استخدام الطاقة في المجزر بتحديد مؤشر استهلاك الطاقة النوعى (SEC) الذى يشير إلي كمية الطاقة المستهلكة (kJ) كل كيلوجرام واحد من الإنتاج. و لتنفيذ الهدف من هذا البحث أجريت سبع عمليات متسلسلة لتجهيز لحوم الدجاج في مجزر دواجن تجارى بمدينة السنطة- محافظة الغربية –مصر وذلك لدراسة تآثير التغيرات في سعة إنتاج المجزر ووزن الطيور الحية المجهزة للذبح ، على الطاقة التي يستهلكها المجزر تحت الظروف المصرية. وقد استخدمت3 أنواع من الطاقة لتشغيل المعدات المستخدمة في عمليات التجهيز السبعة تضمنت الكهرباء والوقود الغازي والطاقة البشرية. حيث يتميز المجزر المختبر بإمكانية التحكم اوتوماتيكيا فى مقادير ونسب مشاركة كل نوع طاقة مستخدم بخطوط التشغيل الالية وفقا للسعة الإنتاجية بالمجزر. وقد تم قياس كميات الطاقات المستهلكة لذبح وتجهيز الدجاج من طيور حية ذات شرائح وزنيه مختلفة هي : (1.7:1.5,1.9:1.7,2.1:1.9كجم) وذلك عند اعداد المجزر للعمل على التوالى بسعات إنتاجية مختلفة هى 1000 ،3000 ، 6000 طائر/ساعة وذلك بأقسام المجزر التالية :- الاستقبال والتعليق ؛ الذبح وتصفية الدم ؛ السمط ؛ نزع الريش ؛ فتح البدن واستخراج الاحشاء ؛ الغسيل والتبريد بالإضافة الى قسم الوزن والتعبئة والتغليف. وقد تم تحديد كفاءة استخدام الطاقة بتحديد مؤشر استهلاك الطاقة النوعى الذى يشير الى كمية الطاقة المستهلكة لكل كيلوجرام واحد من منتج لحوم الدواجن بالمجزر موضوع الدراسة وقد اظهرت النتائج المتحصل عليها ما يلي: * زيادة السعة الانتاجية (طائر/ساعة) للمجزر المختبر من 1000 إلى 3000 ومن 3000 إلى 6000 ادت الى انخفاض استهلاك الطاقة النوعى بالمجزر(كيلوجول/كجم لحم دجاج جاهز للطهى) وذلك بنسب مقدارها 46.4%، و 49.4% على التوالى.*زيادة متوسط وزن الطيور الحية المجهزة للذبح بهذا المجزر وذلك من 1.6 إلى 1.8 كجم ومن 1.8 إلى 2.0 كجم نتج عنه تخفيضات فى كمية الطاقة النوعية اللازمة المجزر لإنتاج كجم من المنتج بنسب مقدارها 19.7 و 25.3 % التوالي .* قدر متوسط استهلاك الطاقة الكهربائية بحوالى 73.8% من الاستهلاك الإجمالي للطاقة فى المجزر المختبر ، بينما قدر متوسطات استهلاك الطلقة الحرارية (طاقة الوقود الغازى) والطاقة البشرية بحوالى 23.43، و 2.77 % على التوالي .* اظهر تحليل بيانات استهلاك الطاقة في العمليات المختلفة لذبح وتجهيز لحوم الدجاج ان معظم الطاقة تستهلك فى عمليات السمط ونزع ريش الدجاج حيث مثلا حوالى29.53%؛36.79%من إجمالي استهلاك الطاقة في المجزر المختبر. بينما نسب استهلاك الطاقة فى العمليات الخمس الأخرى كانت بالترتيب التالي:--تعليق الطيور (1.07%)، ذبح وصفية الدم (1.26%)، عملية اخراج الاحشاء (7.91%)، وعملية الغسيل والتبريد (18.08 ٪) وأخيرا عملية التعبئة (5.37%).* تم اشتقاق المعادلات الرياضية الملائمة والتي تربط العلاقة بين استهلاك الطاقة النوعي والسعات الانتاجية المختلفة للمجزر والتى تساعد على تحديد عوامل التشغيل المثلى للمجزر والتي تؤدى الى توفير الطاقة اللازمة لتشغيل الآلات والمعدات بالمجزر محل الاختبار. وبصفة عامة يوصى البحث بزيادة السعة الانتاجية (طائر/ساعة) للمجزر المختبر وذلك لتحسين كفاءة استخدام وخفض تكاليف الطاقة الكهربية والحرارية المستهلكة في عمليات تجهيز لحوم الدجاج داخل المجزر