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ENERGY CONSUMPTION IN GHEE PROCESSING

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ABSTRACT

An energy accounting study was conducted and the energy intensive operations were identified during the manufacture steps of ghee at a typical processing plants. The energy analysis presented in this study included three types of direct energy namely electrical, thermal and human energy. The accounting process was proceeded for the specific energy consumption in reception, pasteurization and clarification sections of the plant. The results indicated that in reception and pasteurization sections, electric energy operations are significantly more energy consumptive than those of thermal energy operations. It also indicated that in these sections separation, forewarming and cooling are the most energy consumptive operations. The results also showed that these operations required 46.15, 30.36 and 14.69 % of the specific total energy requirement respectively. The results also indicated that total specific energy consumption during cream clarification in (direct cream method) decreased with the increase of both cream fat content and amount of processed ghee. In butter method, the results revealed similar trend as direct cream method, in which total specific energy consumption was decreased with the increase in the amount of ghee during clarification process. On the other hand, in clarification process (of both methods) thermal energy operations are significantly more energy consumptive than those of electrical energy operations. Thermal energy consumption during clarification represent 98.25 and 98.31% of the total specific energy consumption for direct cream method and butter method respectively.

Keywords: Energy account – Ghee processing – Direct cream method – Butter method.

INTRODUCTION

The food processing industry is the link between production and consumption of food. It involves various unit operations such as freezing, heating, drying, pasteurization and sterilization, to assure a uniform supply as foods with minimum product loss to the consumer.

Egypt consumes about 2.83 million-ton of petroleum in food industries, which represent about 22% of the total energy consumed in industry. Of this energy 23% is consumed in dairy industries (OECP, 1996). There have been numerous reports (Heldman and Singh, 1984) in the energy requirements associated with food processing. These reports have led to a series of investigations into energy conservation measures in an effort to reduce energy requirement during food processing.

Carroad *et. al.* (1980) worked on resolving energy use into demand by each unit operation. Classifying energy use as thermal or electrical, allows the processor to identify the most energy consumptive operations where equipment redesign or modification might yield the greatest reduction in demand.

The energy and water costs account for approximately 8-25 % of the total production costs in the dairy industry, depending on the type of product being manufactured, (Fano and Lemhag, 1985) Kay (1984) studied the effect of the volume of milk processed in one day on the energy consumption per kilogram of product. He reported that, this may be important in helping to determine plant operating strategies when limited milk is available for processing.

Determination of energy consumption in three dairy plants was examined by Shokr *et al.* (1995). They determined average specific energy consumption for pasteurized milk, hard cheese, white cheese and yoghurt. (El-Mashad, 1998) reported that. ghee is one of important dairy products in Egypt. Various methods are available for its production, of all the methods the direct cream (D – C) method has certain technological advantages over others because of its simplicity and ease of operational steps.

Energy consumption in churning of cream wasstudied by Pandya *et al.* (1985). They mentioned that, the electrical energy consumption was 7.05 W/kg cream, 15.37 W/kg butter. The variation in consumption was due to variation in quantity of cream, fat % of cream and temperature of churning.

Pandya. And chakraborthy, (1987) studied energy consumption in ghee making by direct cream method. Their results showed that the energy consumption decreased and the recovery of fat in ghee increased with the increase of fat content in cream. They recommended that, high fat cream must be used for ghee making by direct – cream method.

Energy consumption in heat clarification of butter was estimated by Pandya *et al.* (1985). They reported that, the amount of moisture in butter plays an important role in determining the steam requirements during ghee making. The initial temperature of butter also affected steam consumption, but its contribution was insignificant as compared to that of moisture and fat contents.

Singh and Verma (1987) determined energy saving by re-utilizing steam condensate in the manufacture of khoa (27.5 % moisture) from milk (15.9 % TS) from cream (52 % fat). Energy saving by condensate re-utilization through a vaporizer ranged from 59.1 to 67.36 % for khoa and 63.97 – 68.96% for ghee . Further energy savings were achieved using a shell and tube heat exchanger in connection with the vaporizer, 60.35 – 71.62 % for khoa making.

Matouk *et al.* (1999) reported that a reduction in energy consumption will lead to energy conservation as will as a reduction in the level of pollution, which is reflected on improving product quality. They also found that energy conservation efforts on thermal and other operations such as heat recovery from condensate and detergent, isolation of steam pipes regeneration cycle and cleaning technique may be of great importance in the manufacturing of dairy products.

The general objective of this study was to conduct energy accounting and identify the energy intensive operations during the manufacture steps of ghee in a typical ghee processing plants.

The specific objectives were:

1- Quantify specific energy consumption by each unit operations for ghee rocessing.

2- Explore the relationship between specific energy consumption and both of fat percentage and the amount of produced ghee.
3- Examine energy conservation opportunities in processing ghee.
4- Develop a mathematical relationships for energy consumption in ghee processing.

Experimental procedure and measurments

Data used in this research work was obtained from a governmental plants specialized in producing dairy products in Mansoura city, Dakahlia governorate

Experimental procedure :

The experimental work of this study was dealt with energy consumption in ghee processing by direct cream and butter method as follows:

Direct cream method:

Figure (1) shows energy accounting diagram for manufacturing ghee by direct cream method. It can be seen that the milk is pumped from receiving vat to the P. H. E. (plate heat exchanger) where, the milk is cooled down to a level varying from (6 °C – 11 °C) by means of chilled water, and filled to a storage tank. The forewarming process is accomplished in the pasteurizer where the milk is heated to (50 – 55 °C). After forewarming, the milk is pumped to the separator where cream is separated. The cream is converted into ghee by boiling in a stainless steel jacketed vessel which contains a steam trap to condensate the steam. For the experimental work, heat clarification of cream was achieved using 225 kg of cream at varying fat contents of 82, 69, 66 and 63%.

The amount of produced ghee for each fat content was calculated according to the following equation:

$$\text{amount of produced ghee} = \left[\frac{(\text{amount of cream})(\text{cream fat percentage})}{(\text{ghee fat percentage})}\right]$$

After clarification process, ghee is filled into glass or plastic bottles manually and ghee fat percentage was considered as 97.619 %.

Butter method:

In this method ghee was produced in the investigated ghee processing plant using imported butter at 82 % fat content. Heat clarification was achieved by a stainless steel jacketed vessels using different amount of butter and the produced ghee was filled manually in glass bottles.

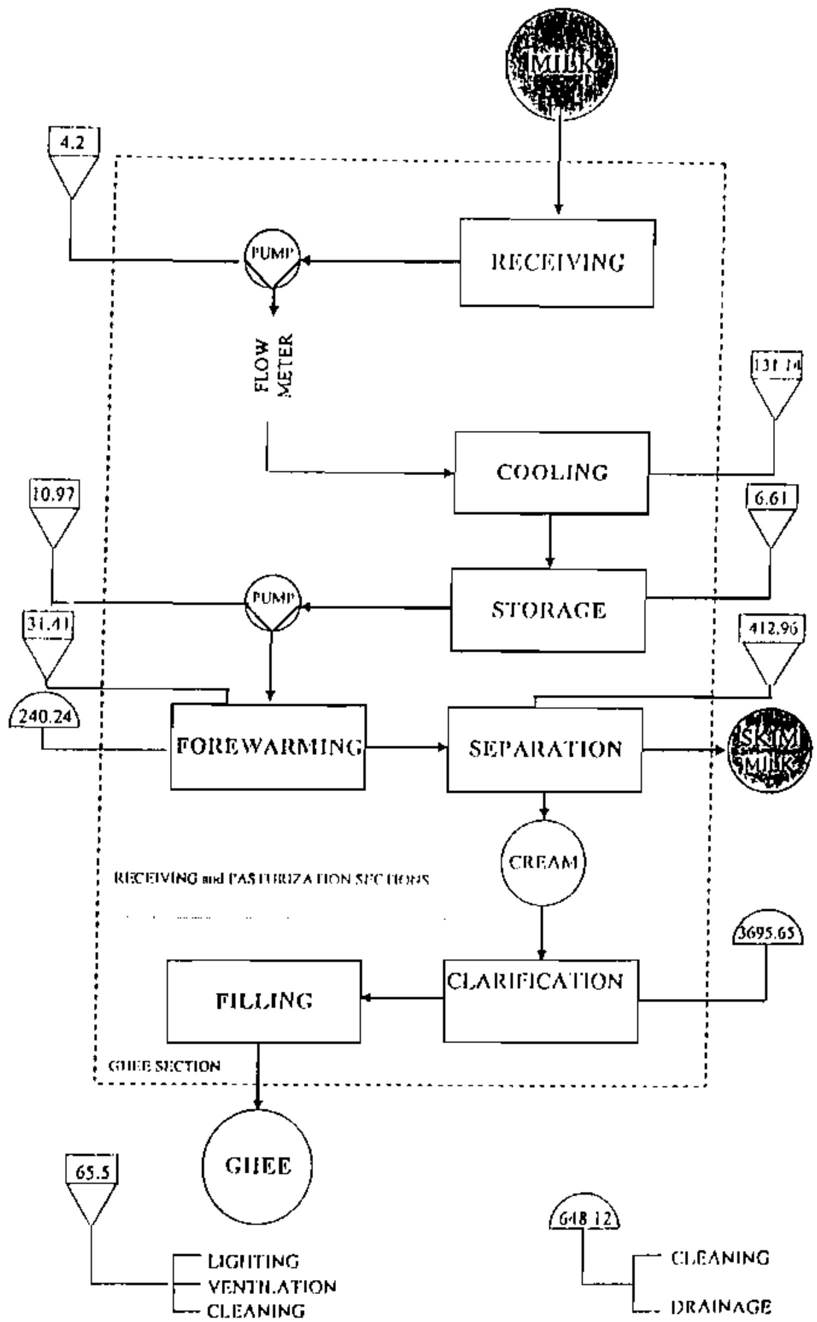

Fig (1) Energy accounting diagram for manufacturing ghee by direct – cream method.

Energy consumed in lightning, ventilation, cleaning, clarification and filling was measured and used for calculating specific energy consumption in producing ghee by butter method.

Measurements:

To estimate energy consumption needed to produce one kilogram of ghee, the electric energy, thermal energy and human energy were computed as follows:

Electric Energy:

Electric energy consumed by driving motors of pumps separators, and fans and also in lightning was measured as follows:

A) Electric energy consumed by motors:

Electric energy consumed by motors was calculated through measuring the line current strength clamp meter and the potential difference values. The following formula was used.

$$Ee = \sqrt{3} \times I \times V \times T \times (pf) \times (cf)$$

Where:

Ee = electrical energy consumption, kJ.

$\sqrt{3}$ = 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 generation this factor was taken as 1.10769 x 104 according to (Singh, 1978).

B) Electric energy consumed in lightning:

To calculate the electrical energy consumed in lightning, the rated power of each lamp was multiplied by the corresponding time of operation

Thermal energy:

Thermal energy consumed in forewarming, clarification, and cleaning processes was estimated as follows:

A) Thermal energy consumed in forewarming .

Thermal energy consumed in forewarming process was estimated using the following formula.

$QT = m . C_p . ?t$,kJ.

Where:

m = mass of cream, kg.

C_p = specific heat of cream, kJ/kg/°C, Cited from **(Mohsenin, 1986).**

?t = temperature difference, °C

Temperature was measured by using the temperature sensor (Thermistor, NUTHERMK), the range of this apparatus is (-50 °C to 1200 °C) with an accuracy of E1± E2.

B) Thermal energy consumed in clarification process.

Thermal energy consumed in clarification process was computed through measuring the steam line pressure from steam gauge, condensate weight, and condensate temperature. This technique was used by (Brusewitz and Singh, 1981)

Energy input by steam was calculated by using the following formula.

$QS = ms (hs + x . hFg)$. , kJ

Where:

QS = energy in steam, kJ.

ms = mass of steam, kg.

hs = sensible heat of steam, kJ/kg.

x = steam quality (decimal). It was assumed to be 100% (Pedrsen *et al.* , 1983)

hFg = heat of vaporization, kJ/kg.

C) Thermal energy leaving with condensate.

Thermal energy of condensate was calculated using the following formula.

$QW = ms\ C_{pW}\ (t_w - t_d)$. ,kJ.

Where:

Q_w = energy in condensate, kJ.

C_{pW} = specific heat at constant pressure, kJ/kg °C.

t_w = condensate temperature, °C

t_d = datum temperature, °C.

D) Thermal energy consumption in cleaning.

To calculate thermal energy consumption in cleaning process, the following formula was used (El-Sahrigi, 1997).

$m_s [(h_s + x . h_{Fg}) - h_m] = m_w (h_m - h_w)$.

Where:

h_m = heat of mixture, kJ/kg.

m_w = mass of water before mixing, kg.

h_w = heat of water before mixing, kJ/kg.

Human energy

Human energy expenditure involved in the processing operations was estimated by assuming that one normal human labor supplies 0.0746 kW (Ezeike, 1987).

RESULTS AND DISCUSSION

Energy consumption in ghee processing is divided into three types, electrical, thermal, and human energy. Electrical energy is mainly used in pumps, milk ccoling, forewarming, separation, lighting and ventilation equipment. Thermal energy is used in forewarming, clarification, and cleaning. Human energy is used for milk receiving, agitation, cleaning and filling.

The obtained results of the present work are discussed as follows:

Energy consumption in reception and pasteurization section

The specific energy consumption (S. E. C.) of each energy type is estimated. Specific energy consumption (S. E. C.) denoted as energy consumed (kJ) per one kg of ghee. Table (1) presents specific energy consumption (S. E. C.) in receiving and pasteurization section. From this table it can be seen that the average specific electrical energy consumption (S. E. E. C.), specific thermal energy consumption (S. T. E. C.), and specific human energy consumption (S. H. E. C.), were 608.083 kJ/kg, 286.69 kJ/kg, and 2.09 kJ/kg respectively. The table also shows that, separation, forewarming and cooling are the most consumptive operations, requiring 46.15%, 30.36%, and 14.69% of all energy, respectively. Other operations do not constitute a significant fraction of the energy used.

Table (1): Specific energy consumption in reception and pasteurization section.

Unit operation	S. E. C. (kJ/kg)		Total kJ/kg	% of Total
	Electrical	Thermal		
receiving pumps	4.2	---	4.2	0.47
Cooling (P H E)	131.41	---	131.41	14.69
agitation	6.61	---	6.61	0.74
Pump	10.97	---	10.97	1.22
pasteurization	31.41	240.24	271.65	30.36
separation	412.96	---	412.96	46.15
lighting	0.913	---	0.913	0.1
ventilation	0.77	---	0.77	0.09
cleaning	8.84	46.45	55.29	6.18
Total	608.083	286.69	894.77*	100

*** Adding 2.09 kJ as a human energy.**

Energy consumption during clarification process of direct cream method:

Energy consumption during clarification process may be classified as electrical energy which is used for lighting, and ventilation, thermal energy which is employed for clarification and cleaning and human energy which is utilized for agitation, filling, and cleaning.

Energy consumption in clarification of cream at varying fat content was calculated by using 225 kg of cream at varying fat contents of (82, 69, 66, and 63%).

The data obtained of these tests are recorded and listed in Table (2) and plotted in Figures (2 to 6). Inspection of these data showed that, total specific energy consumption (T. S. E. C.) is decreased with the increase of cream fat content and amount of processed ghee. This was mainly due to reduced fat losses in ghee residue because of a lower solids not fat content in high fat cream, these findings are in agreement with those reported by Pandya and Chakraborthy. , 1987.

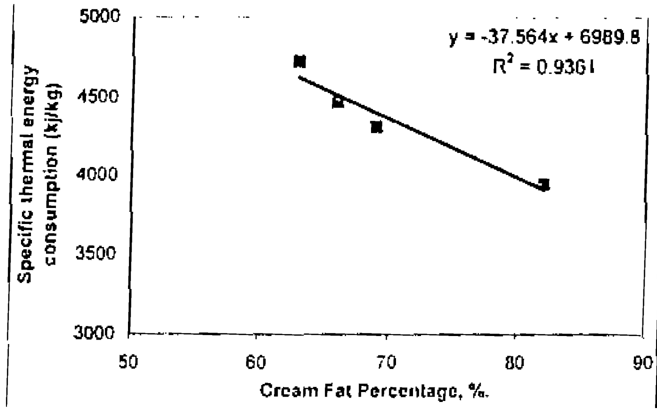

Fig. (2) : Relation between cream fat percentage and specific thermal energy consumption.

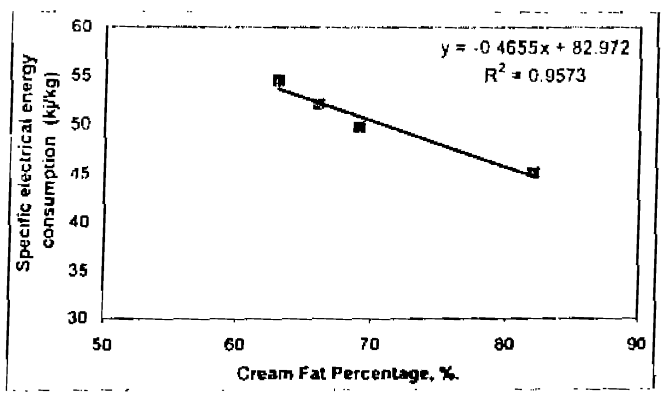

Fig. (3) : Relation between cream fat percentage and specific electrical energy consumption.

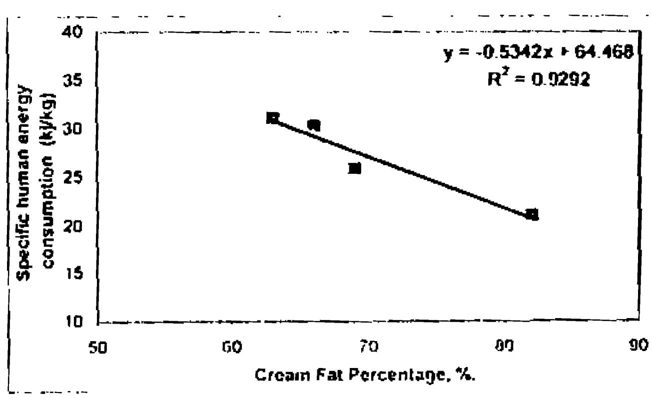

Fig. (4) : Relation between cream fat percentage and specific human energy consumption.

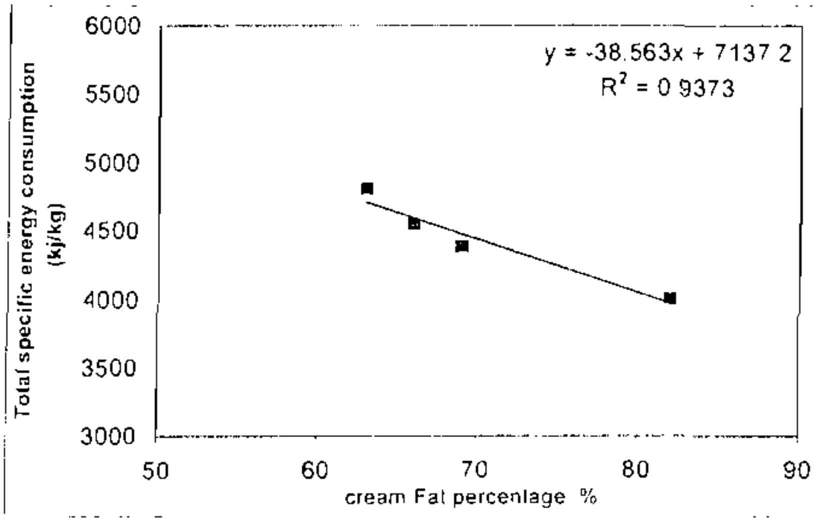

Figure (5) : Relation between fat, % of cream and total specific energy consumption

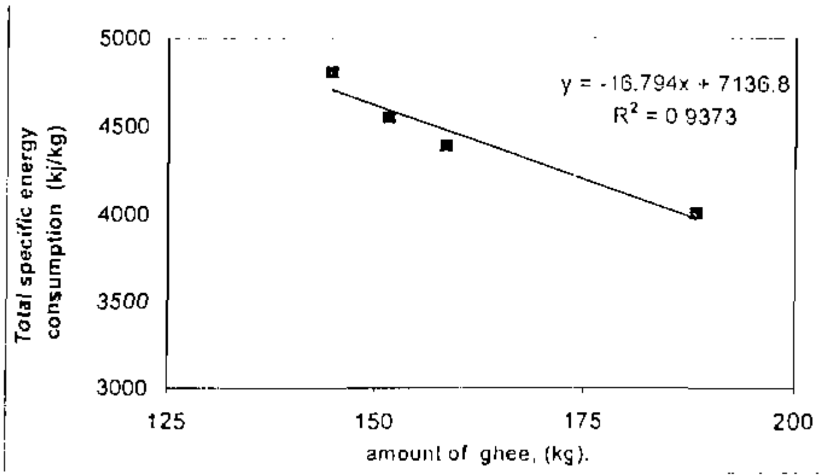

Figure (6) : Relation between amount of produced ghee (kg) and total specific energy consumption.

Table (2): Specific energy consumption in clarification of cream at different fat percentage s.

Fat % of cream	kg Cream	kg Ghee	S.H.E.C. kJ/kg	S.E.E.C. kJ/kg	S.T.E.C. kJ/kg	T.S.E.C kJ/kg
82	225	188.27	21.05	45.16	3944.12	4010.33
69	225	158.42	25.84	49.78	4310.67	4386.29
66	225	151.53	30.31	52.10	4466.10	4548.51
63	225	144.64	31.10	54.50	4720.39	4805.99
Average			27.08	50.39	4360.32	4437.78
%			0.61	1.14	98.25	100

The obtained data of specific energy consumption in clarification of cream at different fat percentages were fitted to a linear regression analysis and the obtained regression equations the best fit were as follows:

$Y_{sth} = 6989.8 - 37.554\,F$ $R^2 = 0.936$

$Y_{s\,elec} = 82.972 - 0.4655\,F$ $R^2 = 0.957$

$Y_{s\,hum} = 64.468 - 0.5342\,F$ $R^2 = 0.929$

$Y_{TS} = 7137.2 - 38.563\,F$ $R^2 = 0.9373$

$Y_{TS} = 7136.8 - 18.794\,M$ $R^2 = 0.9373$

Where

Y_{sth} = specific thermal energy consumption (kJ/kg)

$Y_{s\,elec}$ = specific electrical energy consumption (kJ/kg)

$Y_{s\,hum}$ = specific human energy consumption (kJ/kg)

Y_{ST} = specific total energy consumption (kJ/kg)

F = fat percentage of cream (%)

M = amount of ghee (kg)

On other hands, the results show that, specific thermal energy in clarification process represents 98.25% of total specific energy consumption and both specific electrical energy and human energy represent only 1.14 and 0.61% respectively. For this reason, the items of specific thermal energy utilized in the overall process was analyzed and presented in Table (3) and Figure (7). The results of analysis show that the specific thermal energy utilized only for clarification process represents 86.19% of total specific thermal energy while the specific thermal energy utilized for drainage and cleaning represent 10.79 and 3.02% respectively. This means that, about 470.40 kJ/kg of thermal energy are lost in draining water which can be used as a feed water of the boiler or it can be utilized for cleaning process. This energy conservation process may lead to saving of about 12.2% of thermal energy used in overall clarification process. These results are in agreement with those obtained by (Ahmed, 1992 and Matouk, *et al.,* 1999).

Table (3) Specific thermal energy items at different fat percentages of cream:

Fat % of cream	kg Cream	kg Ghee	S.T.E.C. in clarification kJ/kg	S.T.E.C. in drainage kJ/kg	S.T.E.C. in cleaning kJ/kg	S.T.E.C. kJ/kg
82	225	188.27	3383.29	465.35	95.48	3944.12
69	225	158.42	3719.36	462.06	129.25	4310.67
66	225	151.53	3824.735	467.10	174.265	4466.10
63	225	144.64	4105.23	487.07	128.09	4720.39
Average			3758.15	470.40	131.77	4360.32
%			86.19	10.79	3.02	100

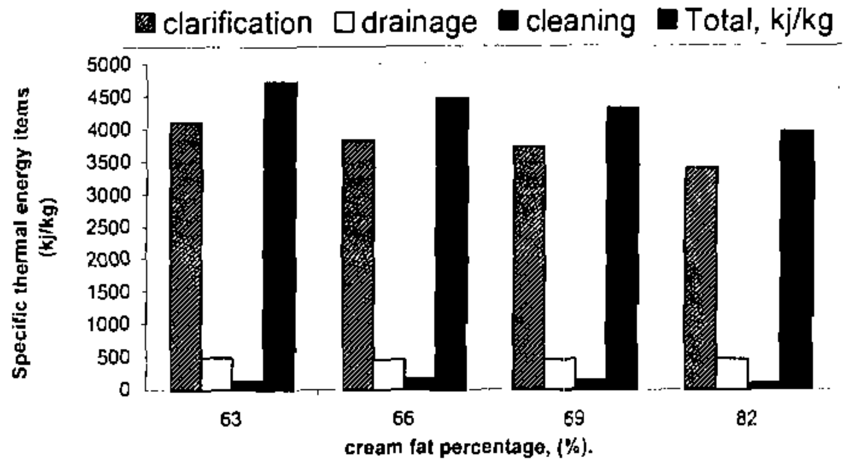

Fig. (7) Specific thermal energy items at different cream fat percentage for direct cream method.

Specific energy consumption during clarification of butter (in butter method):

The relation between amount of ghee production and energy consumption in clarification process was estimated at 82% fat content as used in the investigated (butter method) ghee production plant.

The obtained data of these tests were recorded and listed in Table (4). It revealed that, increasing amount of ghee tended to decrease specific thermal energy consumption (S. T. E. C.) during clarification process. The Table also shows that, average total specific energy consumption (T. S. E. C.) was 4246.43 kJ/kg of ghee and the average thermal energy consumption (S. T. E. C.) represents 98.31% of (T. S. E. C.). On the other hands, both average specific electrical energy consumption and human energy consumption represent only 1.16 and 0.53 of (T.S.E.C) respectively.

Linear regression analysis was also applied to relate the amount of ghee production with thermal and total energy consumption. Results of analysis decleared that thermal and total energy consumption increased linearly with the decrease of the amount of ghee in the range of 125 to 210 kg as shown in Figures (8) and (9) respectively. The obtained regression equations for the best fit were as follows:

$Y_{th} = 6419.8 - 12.921\ M$ $\qquad R^2 = 0.963$

$Y_{total} = 6592.6 - 13.503\ M$ $\qquad R^2 = 0.963$

Where

Y_{th} = thermal energy consumption (MJ)

Y_t = total energy consumption (MJ)

M = amount of ghee production (kg)

Table (4): Specific energy consumption in ghee processing using butter at 82% fat content.

kg (ghee)	S.H.E.C. in kJ/kg	S.E.E.C. in kJ/kg	S.T.E.C. in kJ/kg	T.S.E.C. kJ/kg
210	19.22	35.43	3786.44	3841.09
190	21.05	40.16	3944.12	4005.33
170	22.87	44.87	4101.76	4169.5
125	26.84	76.31	4866.66	4969.81
Average	22.5	49.19	4174.75	4246.43
%	0.53	1.16	98.31	100

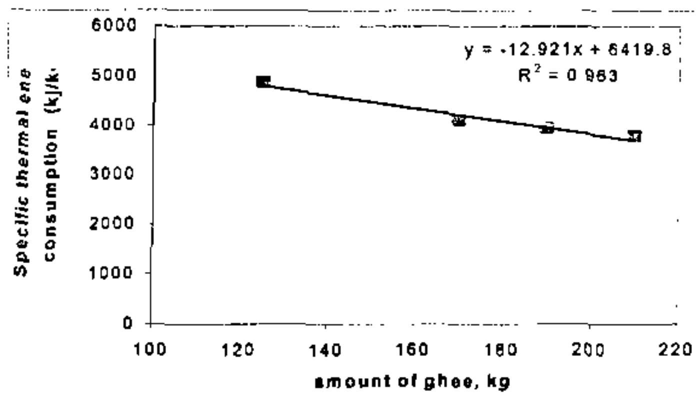

Fig. (8) : The relationship between amount of ghee and specific thermal energy consumption.

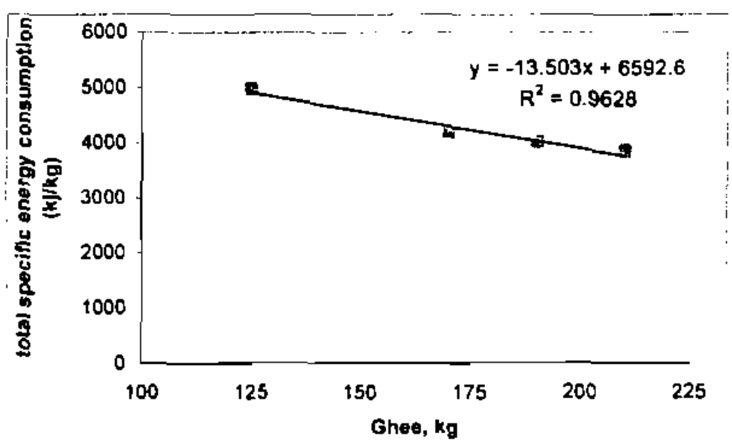

Fig. (9) : The relationship between amount of ghee and total specific energy consumption.

CONCLUSIONS

1. The average specific electrical, thermal and human energy consumption in receiving and pasteurization section of direct-cream ghee production method were 608.083, 286.69, and 2.09 kJ/kg respectively. Separation, forewarming and cooling are the most consumptive operations. Other operations don't constitute a significant fraction of energy used in this stage.
2. Total specific energy consumption in clarification process of direct cream method decreased with the increase of cream fat content. Specific thermal energy represent 98.25% of total specific energy consumption followed by specific electrical and human energy which represent 1.14% and 0.61% respectively.
3. Specific thermal energy represent 86.19% of total thermal energy utilized in clarification process of direct cream method, while specific thermal energy used for drainage and cleaning represent 10.79 and 3.02% respectively. This means that about 470.40 kJ/kg of thermal energy lost in drainage water of poiler can be used for cleaning process.
4. Specific total and thermal energy consumption decreased linearly with the increase of the amount of ghee for both direct cream and butter ghee production methods.

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دراسة على الطاقة المستهلكة فى تصنيع السمن

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أجريت هذه الدراسة لحساب الطاقة المستهلكة خلال مراحل التصنيع المختلفة للسمن حيث شملت الحسابات ثلاث أنواع من الطاقة المستخدمة تمثلت فى الطاقة الحرارية ، الطاقة الكهربية وكذلك الطاقة البشرية. ولقد أظهرت النتائج المتحصل عليها ما يلى :

١- متوسط الطاقات النوعية المستهلكة خلال مرحلة الاستقبال والبسترة فى طريقة التسييح المباشر للقشدة وصلت إلى حوالى ٦٠٨,٠٨٣، ٢٨٦,٦٩، ٢,٠٩ كيلوجول / كجم وذلك للطاقة الحرارية، الكهربية ثم البشرية على التوالى .

٢ – سجلت عمليات الفصل،التسخين المبدئى ، وكذلك التبريد أعلى معدلات استهلاك للطاقة خلال مراحل الاستقبال والبسترة حيث وصلت النسب المئوية للطاقة المستهلكة فى تلك العمليات إلى حوالى ٤٦,١٥، ٣٠,٣٦، ١٤,٦٩% على التوالى فى حين مثلت باقى العمليات حوالى ٨,٥٣% من الطاقة الكلية المستهلكة في طريقة التسييح المباشر للقشدة.

٣ – انخفضت الطاقة النوعية المستهلكة خلال عملية التصفية بزيادة نسبة الدهن في القشدة المستخدمة. كما مثلت الطاقة الحرارية المستهلكة خلال تلك العملية حوالى ٩٨,٢٥% من الطاقة الكلية تلى ذلك كل من الطاقة الكهربية والبشرية حيث وصلت النسبة المئوية لها الى حوالى ١,١٤، ٠,٦١% على التوالى .

٤ – أظهرت نتائج تحليل مراحل استهلاك الطاقة الحرارية خلال عملية التصفية في طريقة التسييح المباشر للقشدة أن الطاقة الحرارية المفقودة خلال كلا من مياه الصرف الناتجة من الغلايات وكذلك مياه التنظيف تمثل حوالى ١٠,٩٥%، ٣,٠٥% على التوالى مما يعنى أن هناك فقد في الطاقة الحرارية المستهلكة خلال عملية الصرف يقدر حوالي ٤٧٠,٤٠ كيلو جول/ كجم يمكن توفيرها بإعادة استخدام مياه الصرف الناتجة عن الغلايات مره أخرى فى عملية التنظيف.

٥ – أوضحت النتائج انخفاض كمية الطاقة النوعية الكلية المستخدمة في عملية التصنيع بصورة خطية مع زيادة كمية السمن المنتج وذلك عند انتاج السمن بكلا من طريقتي التسييح المباشر وطريقةالزبدة.