Zagazig J.Agric. Res., Vol .31 No.(1) 2004 **307 - 323**

THE ENERGY CONSUMED IN MANUFACTURE SOME FOOD PRODUCTS (I) THE ENERGY CONSUMPTION FOR PROCESSING MILK BY THE (UHT) AND (HTST) SYSTEMS.

Abd El-Wahab M.K*.; M.A. El-Shazly* ; F.H. Badr and W.M. Hanafy***

**Agriculture. Engineering. Department., Faculty. of Agric., Zagazig University.*

*** Food Science Department., Faculty. of Agric., Zagazig University.*

Received 2 / 10 / 2003 ***Accepted 22 / 10 / 2003***

ABSTRACT: Energy consumption in various unit operations of both Ultra-High-Temperature (UHT), and a conventional High-Temperature-Short-Time (HTST) pasteurization systems were evaluated and compared. The (UHT) system consumed 437.665 MJ/ton milk while the (HTST) system, consumed 276.954 MJ/ton milk. The energy consumption/recovery of the regenerator, preheater (heater), homogenizer and cooler were comparable for both systems. The total consumed energy for different packaging methods was also evaluated.

Key words: Energy, consumption, packaging, UHT, HTST, milk.

INTRODUCTION

The milk sterilized using a steam infusion (UHT) process has been found flavor able compared to the (HTST) pasteurized milk *(Nahra and Westhoff, 1980)*. The processing system (UHT) of food products requires a higher quantity of thermal and electrical energy in the processing plant than conventional processing system (HTST) *(Chandarana et al., 1982)*. *Biziak et al. (1982)* revealed that the energy requirements of a shell and tube (UHT) system were 358 and 437 KJ/kg milk for flow rates of 625, 1055 and 1367 Kg/h and processing temperature ranged between 138 and 149C°while *Chandaran et al., (1984)* revealed that the energy requirements for process. It was 217-228 KJ/kg that value excluded the energy required for post processing refrigeration. The consumption of fuel oil, and electricity per kg product in all raw milk factories were about 707.35 and 230.2 KJ receptively *(Yoon, 1983)*. The thermal energy used in polish dairies for processing1000 liter milk consumed an average of 1737 MJ *(Woidalski and Malejko, 1984)*. (UHT) system was used to sterilize raw milk at 138C°, 148C° and 154C°. Energy consumption/recovery of various (UHT) operations consumed 476-570 KJ/kg milk, versus 120-131 KJ/kg milk in the (HTST) system *(Frey et al., 1984)*. The (UHT) process estimated in net energy saving because the product does not require an energy for post processing refrigeration *(Chandrana et al., 1984)*. Pasteurized milk consumption of fuel oil and electrical energy average 595 and 170 MJ/ton milk intake respectively *(Okoth, 1990)*. The energy consumption in modern milk industries for pasteurized and sterilized milk in bottles from heating and electrical energy were 165, 200 and 55, 70 K Wh/ton *(Eliza and Diakows, 2000)*.

Measuring of the energy consumption for each unit operation identifies the energy intensive components of the processing system and components from which energy can be recovered and reused.

The objectives of this study are to:

1- evaluate and compare the energy consumption for both (UHT) and (HTST) systems.

2- Quantitatiny energy requirements of four different packing methods.

MATERIALS AND METHODS

The experiments were carried out in "Green Land" Middle East Co. for Food and Dairy Production at 10th of Ramadan City. The milk flow diagram for (UHT) and the (HTST) systems was shown in Fig. (1). Milk in the (UHT) system was preheated from 17 to 80C°, homogenized and then sterilized using steam. The processing at temperature of UHT was 137C° with a holding time of 4 seconds. In the (HTST) system the milk was heated from 6 to 87.5C° with a holding time of 30 seconds. The temperature and holding times for both processes were regarded to be selected as in the fluid milk industry. The milk flow rate for both systems was 10 Tons/h±5%. Different instrumentation were used for monitoring the processing system included flow rate counter

(PLCS) model A/B. Lund. Sweden (flow rate), at points (8-19-20), digital temperature thermometer OMRON model (E_5C_5-RIP X 521) (temperature), at points (3-4-6-7-11-15-19-20), digital multimetere model ME-540 with a double jak AC and DC (temperature-electrical energy), vapor rate counter DP cell foxboro (vapor rate), at points (6-7), digital clampmeter 750 AKEW-SNAP model 2007 with a double jak AC and DC (electrical energy), at points (1-2-3-5-6-9-10-12-14-19-21-22-23-24-25).

The unit operations analyzed were $regenerator_1$, $homogenizer_1$, separator cream sterilization, microfilteration, heater, mixing device, $cooler_1$, $regenerator_2$, preheater, $homogenizer_2$, sterilizer, $cooler_2$, tetra brick aseptic, tetra capping, applicator, tubex and shrink. These unit operations were run as follows:

1-Unit operations of (HTST) system:

The unit operation of that system are referred by the symbols from A to T in fig. (1).

$Regenerator_1$ (K)

The regenerator section was a plate heat exchanger Fig. (1). Hot processed milk enter the regenerator from the top of head plate through crossover holes between the plates while the raw milk entering the regenerator from the bottom of head plate which flowing in the opposite direction against the other side of the plate heater. The temperature of raw milk entering the regenerator was 6C° and it was heated to 55C°. The processed milk entered the regenerator at 87C° and it was cooled to 38C°.

$Homogenizer_1$ (O)

The $homogenizer_1$ basically a horizontaly mounted 3-piston positive displacement pump with belt in homogenizing device, the milk homogenized at 4.6 MPa.

Separator (L)

The standered equipments included are motor, foundation plate and automatic pneumatic brake. The unprocessed milk fed into the separator powel from the bottom which separate it into skimmed milk and cream.

Cream Sterilization Device (M)

It was a free standing plate heat exchanger with cooling, regenerative and heating section. The cream sterilized at 130C° with a holding time of 2-4 seconds.

Microfilteration Device (F)

It was used to separate microorganisms from skimmed milk, the device made of stainless steel including membrane with pore size of microfilters CA 1.4 μm and high pressure pump.

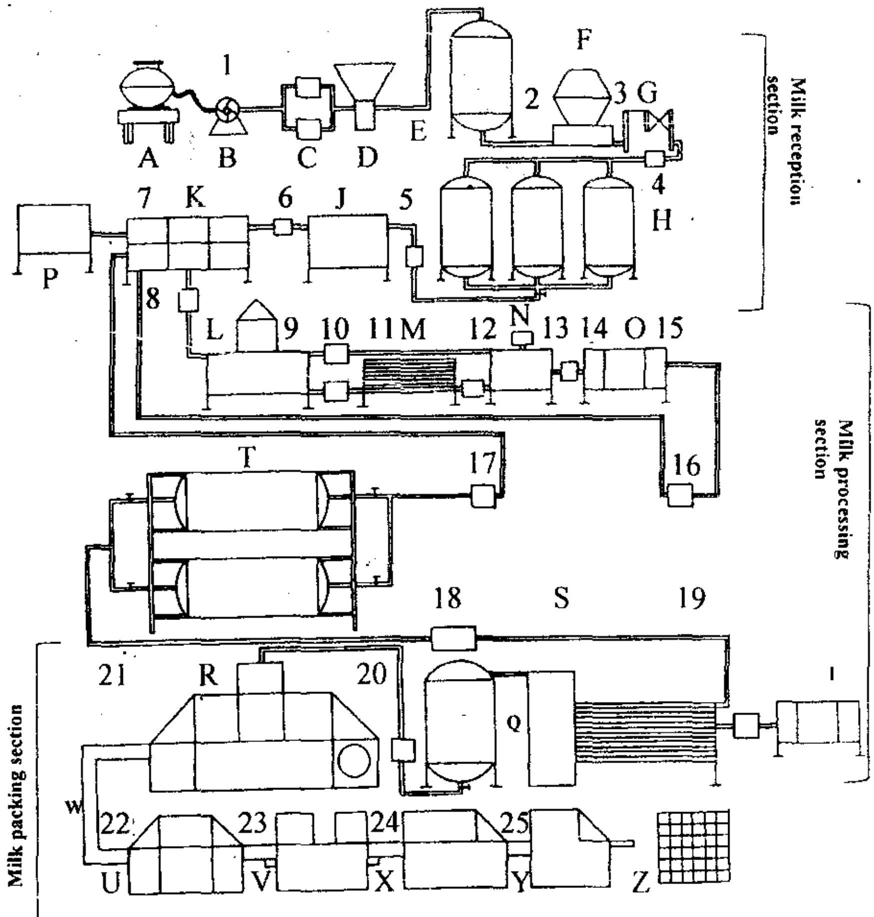


Fig. (1): Milk production line plant (A)

Symbol	Part Name	Symbol	Part Name
A	Road Tanker	O	Homogenizer
B	Centrifugal Pump	T	Pasteurized milk storage tanks
C	Two filter	S	UHT device
D	Powder milk mixing(chat)	I	UHT homogenizer
E	Reception silo	Q	Packaging tank
F	Micro Filtration	R	Tetra brick aseptic packaging
G	Cooler	W	Conveyer
H	Three storage tanks	U	Tetra capping applicator
J	Balance tank	V	Tubex straw applicator
K	Plate heat exchanger(T-T-L-B)	X	Tetra cardboard packer
L	Separator	Y	Shrink
M	Cream sterilization device	Z	Product
N	Mixing	P	Boiler

Heater (K)

It was also a plate heat exchanger. The milk temperature increased by about 33C° to pasteurization temperature 87C°.

Mixing Device (N)

It was used to mix skimmed milk with cream.

Cooler$_1$ (K)

It was a refrigeration system, consists of compressor shell and tube condenser, evaporator coil and shelled water tank. The milk was cooled from 38C° to 6C°.

2-Unit Operation of (UHT) system:

The unit operations of that system are referred by symbols from S to Q in fig. (1).

Regenerator$_2$ (S)

The regenerator was a double tube heat exchanger, cooled milk flowed in the outer tube while hot processed milk flowed in the inner tube. The temperature of incoming milk enter the regenerator was 17C° and it was heated to 80C°. The processed milk enters the regenerator at 137C° and it was cooled to 74C°.

Preheater (S)

The preheater was also a double tube heat exchanger. The milk temperature increased by about 13C° to a preheat temperature 93C°.

Homogenizer$_2$ (I)

The milk was homog-enized at 5.8 MPa.

Sterilizer (S)

The milk temperature increased by about 44C° to be 137C°.

Cooler (S)

The cooler was also a double tube heat exchanger. The milk cooled from 74C° to 25C°.

3-The investigated packa-ging units:

This unit are referred by symbols from R to P. in fig. (1).

Tetra Brick Aseptic Machine (R)

It is an splicing unit with double reel for packaging milk in packaging volum 200 ml, 250 ml, 500 ml and 1 litre.

Tetra Capping Machine (U)

They were a capping unit provids packages with plastic caps.

Applicator and Carton (Tetra cardboard packer) (X)

They were a packer to collect packages in small groups in wrapping box.

Tubex Straw Applicator (V)

They were a hot melt gun to provide packages with tubex.

Shrink Machine (Y)

They were a double reel for wrapping material to wrappe the box with plastic covers.

Estimation of thermal and Electrical:

The Thermal energy was estimated according to Mills (2002). as follow.

$$Q = m\,c\,(Tin - Tout) \quad (1)$$

Where:

Q	rate of heat transferred (kJ/h)
m	mass flow rate (kg / h)
c	specific heat (kJ/kg C°)
Tin	temperature of inlet fluid (C°)
Tout	temperature of outlet fluid (C°)

While the elecrical was estmed according to Jimmie (2002) as follow.

$$P = \sqrt{3}\ V\ I\ \cos \O \text{ watt / h} \quad (2)$$

Where:

P	Motor electrical power (W) J/S
V	Volt
I	Ampere
Ø	Power angle

RESULTS AND DISCUSSION

1- Energy distribution in different unit operations of (HTST) and (UHT) systems.

The energy required consumed by each unit operation was shown in figs. (2 and 3). It can be was noticed that:

For (HTST) system

Regenerator

The raw milk absorbed 191 MJ thermal energy/ton of milk whereas the product lost 212 MJ with regenerator thermal efficiency 90%.

Homogenizer

The homogenizer where the largest pump in the system required an average of 11.991 MJ/ton of milk electrical energy, total energy for homogenization represents a percentage of 4.33% of total energy required for milk processing.

Separator

The separator required an average of 6.662 MJ/ton of milk electrical energy, total energy for separation represents a percentage of 2.41% of the total energy.

Cream Sterilization device

It require an average of 7.680 MJ/ton of milk thermal energy or 109.764 MJ/ton of cream while cooling cream require 4.830 MJ/ton of milk electrical energy or 69 MJ/ton of cream, in addition to the thermal energy the cream vaccum device required 1.801

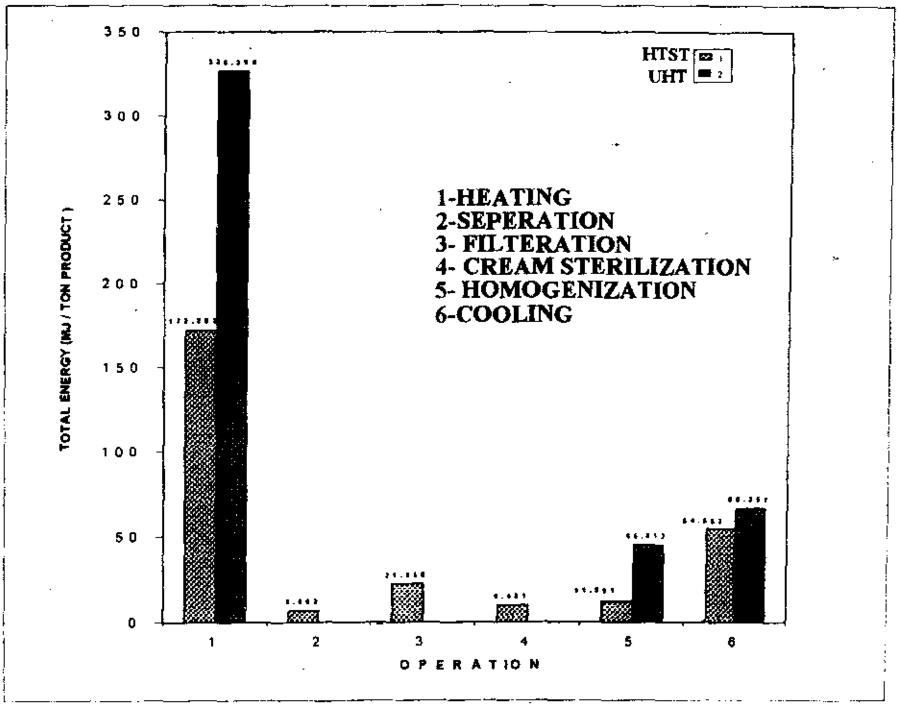
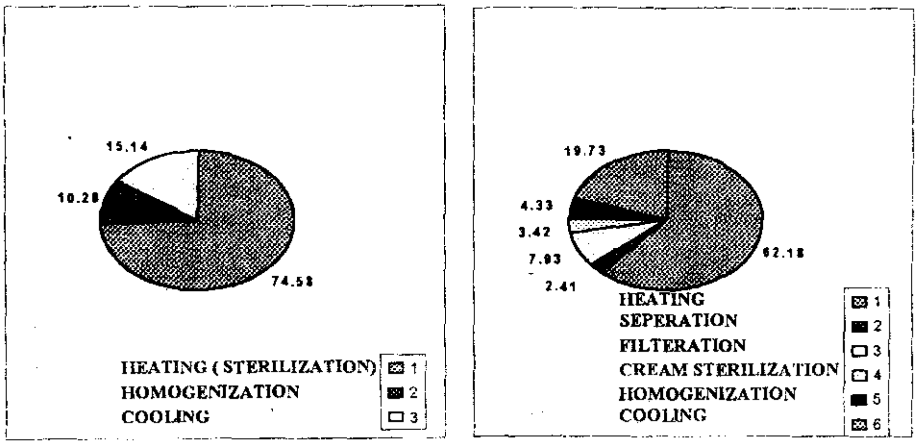


Fig. (2): Comparison between the energy requirements for HTST milk and UHT milk systems.



HTST MILK UHT MILK

FIG.(3) : The percent of energy distribution for different operation of UHT milk and HTST milk systems .

MJ/ton of milk electrical energy. The total energy for cream sterilization represents a percentage of 3.42% of total energy required for milk processing.

Filtration

The filtration require an average of 21.956 MJ/ton of milk electrical energy with a percentage of 7.93% of the total energy.

Heater

The milk absorb 165 MJ/ton of milk thermal energy in addition to the thermal energy the hot water pump required 7.202 MJ/ton of milk electrical energy. The total energy for heating represents a percentage of 62.18% of the total energy.

Cooler

The milk lost an average of 124.8 MJ/ton of milk thermal energy before being packaged. The cooler require 54.662 MJ/ton of milk electrical energy with cooling efficiency 60%. The total energy for cooling represents a percentage of 19.73% of total energy.

For (UHT) system

Regenerator

The incoming milk absorbed 246 MJ/ton of milk thermal energy whereas the product lost 273 MJ/ton.

Preheater

The milk absorb 67.6 MJ/ton of milk thermal energy.

Homogenizer

It require an average of 45.012 MJ/ton of milk electrical energy, total energy for homogenization represents a percentage of 10.28% of total energy required for milk processing.

Sterilizer

The consumption energy by sterilizer was 228.8 MJ/ton of milk thermal energy with thermal efficiency 75%, in addition to the thermal energy the sterilizer required 29.996 MJ/ton of milk electrical energy. The total energy for preheated in sterilization process represents a percentage of 74.58% of total energy required for milk processing.

Cooler

The milk lost an average of 191 MJ/ton milk thermal energy whereas the cooler require 66.257 MJ/ton of milk electrical energy with cooling efficiency 60%. The total energy for cooling represents a percentage of 15.14% of total energy required for milk processing.

2- Total energy required for (HTST) and (UHT) milk systems:

The energy required for milk processing under two different systems of (HTST) and (UHT) was evaluated and shown in Fig. (4) and Table (1). It was noticed that the use of (UHT) system was accompanied with an increase in energy consumption with a percentage of 58% comparing with (HTST) system. The values of energy requirements were 276.954 and 437.665 MJ/ton of milk for (HTST) and (UHT) systems respectively. The increase of energy requirement in the case of using (UHT) system can be attributed to that, (UHT) system requires more heat energy compared to (HTST) system.

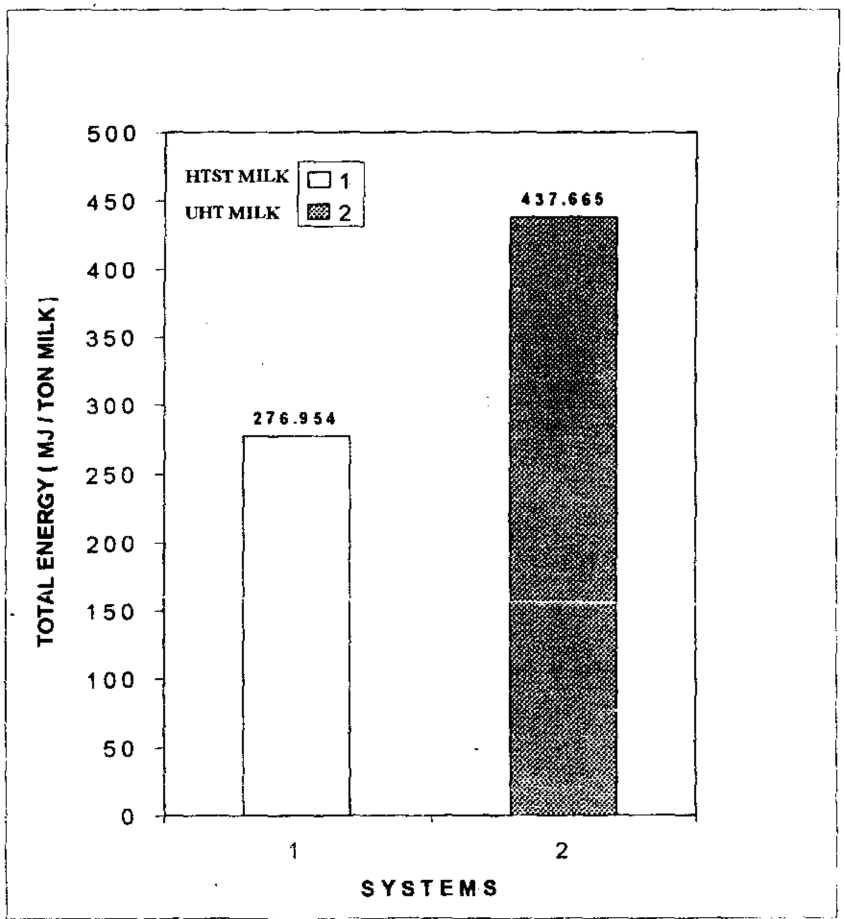


Fig. (4): Comparison between the energy requirements for HTST milk and UHT milk

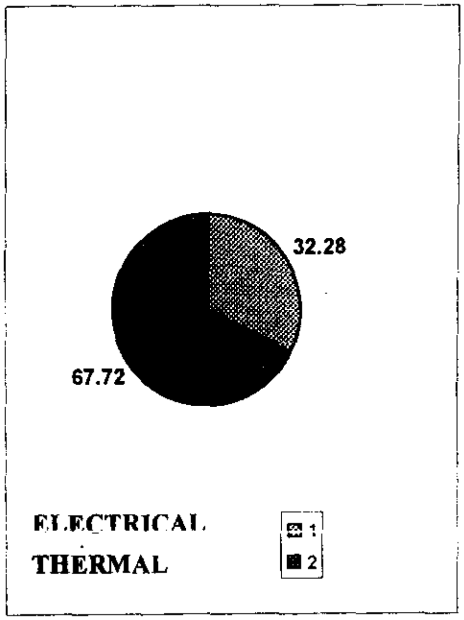
Table (1): Average energy consumption for each individual operation in both HIST and UHT milk pasteurized systems.

	Consumed energy per Ton / Operation	Milk HTST system				Milk UHT system			
		Electrical KW.h(MJ)	Thermal (MJ)	Total E(MJ)	Percent of T.E	Electrical KW.h(MJ)	Thermal (MJ)	Total E(MJ)	Percent of T.E
Processing	Heating (pasteurization	2	(165.000)	(172.202)	62.18	8.33	(296.400)	(326.396)	74.58
	& sterilization)	(7.202)				(29.996)			
	Separation	1.85	---	(6.662)	2.41	---	---	---	---
		(6.662)							
	Filtration	6.1	---	(21.956)	7.93	---	---	---	---
		(21.956)							
	Cream Sterilization	0.5	(7.680)	(9.481)	3.42	---	---	---	---
		(1.801)							
	Homogenization	3.33	---	(11.991)	4.33	12.5	---	(45.012)	10.28
		(11.991)				(45.012)			
	Cooling	15.18	---	(54.662)	19.73	18.4	---	(66.257)	15.14
		(54.662)				(66.257)			
Total		(104.274)	(172.680)	(276.954)	100%	(141.265)	(296.400)	(437.665)	100%
Percent of T.E		37.65	62.35	100%		32.28	67.72	100%	

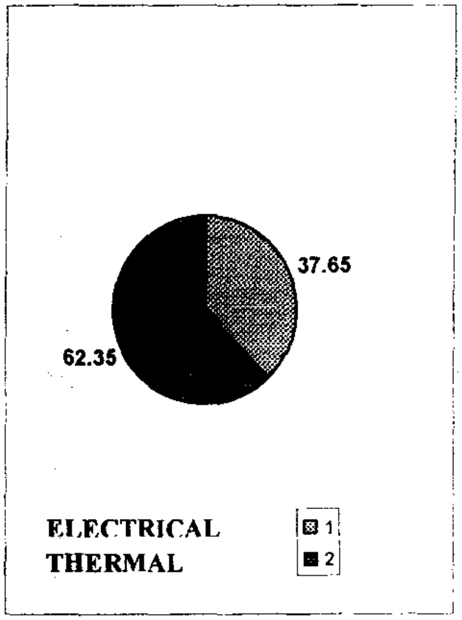
Electrical and thermal energy consumption:

Fig. (5) shows both of electrical and thermal energy consumed through the two deduced milk processing under different systems. It is cleared that, the thermal energy requirements of were 172.680 and 296.400 MJ/ton of milk.

That represent of 37.65 and 32.28% of total energy required for processing under (HTST) and (UHT) systems respectively. From these results it can be deduced that, thermal energy represents the greater part of energy consumed in milk 109.82% compared to electrical ones for different systems.



MILK UHT SYSTEM



MILK HTST SYSTEM

FIG.(5): The percent of electrical and thermal energy consumed for HTST milk and UHT milk systems .

These values represent of 62.35 and 67.72% of total energy consumption While the consumed electrical energies were 104.274 and 141.265 MJ/ton milk.

3- Energy requirements for different packaging methods

The comparison between different machines of packaging according to the energy required for each was conducted using different machines named Tetra Brick Aseptic packaging (A), Applicator and carton (B), Tubes straw applicator (C), Capping applicator (D) and Shrink (E), all experiments were carried out under different packaging volumes were (200, 250, 500 and 1000 ml). The obtained results were shown in Fig. (6, 7) and listed in Table (2) which indicated the greatest consumed energy of packaging 119.071 MJ/ton was accompanied with machine (B) and the least one under machine (D) compared with the other.

Added to that it was also noticed that the use of volume packaging of 1 litre saved the energy required for packaging with percentage ranged from 44.66% to 65.22%, from 26.54% to 46.94% and from 26.09% to 47.82% comparing with the other volumes for A, B and E machines respectively.

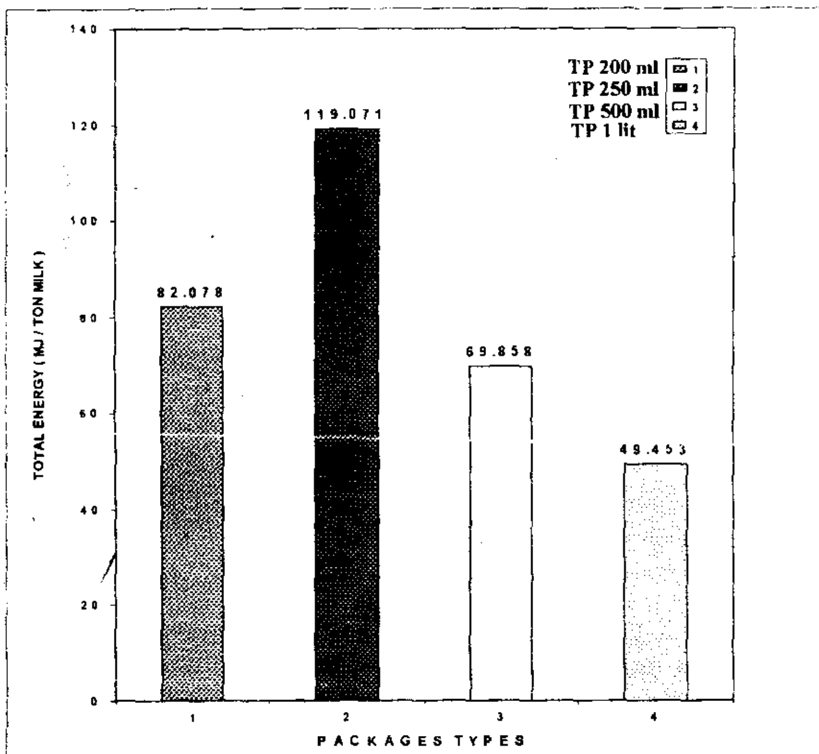


FIG.(6) : The consumed energy for packaging milk by different types of tetra pack packages .

Table (2) The consumed energy per ton for packaging milk by different types of tetra packages.

Packaging Machine Type / Unite Operation	TP 200 ml Kw.h(MJ)	Percent of T.E	TP 250 ml Kw.h (MJ)	Percent of T.E	TP 500 ml Kw.h(MJ)	Percent of T.E	TP 1 lit Kw.h(MJ)	Percent Of T.E
Tetra Brick Aseptic Packging	12.73 (45.828)	55.83	23 (82.821)	69.55	11.34 (40.811)	58.42	8 (28.807)	58.25
Applicator and carton	1.63 (5.882)	7.17	1.63 (5.882)	4.94	1.2 (4.321)	6.19	.87 (3.121)	6.31
Tubex straw applicator	.77 (2.761)	3.36	.77 (2.761)	2.32	---	---	---	---
Capping applicator	---	---	---	---	1.2 (4.321)	6.19	.87 (3.121)	6.31
Shrink	7.67 (27.607)	33.64	7.67 (27.607)	32.19	5.67 (20.405)	29.20	4 (14.404)	29.13
Total	22.8 (82.078)	100%	33.07 (119.071)	100%	19.41 (69.858)	100%	13.74 (49.453)	100%

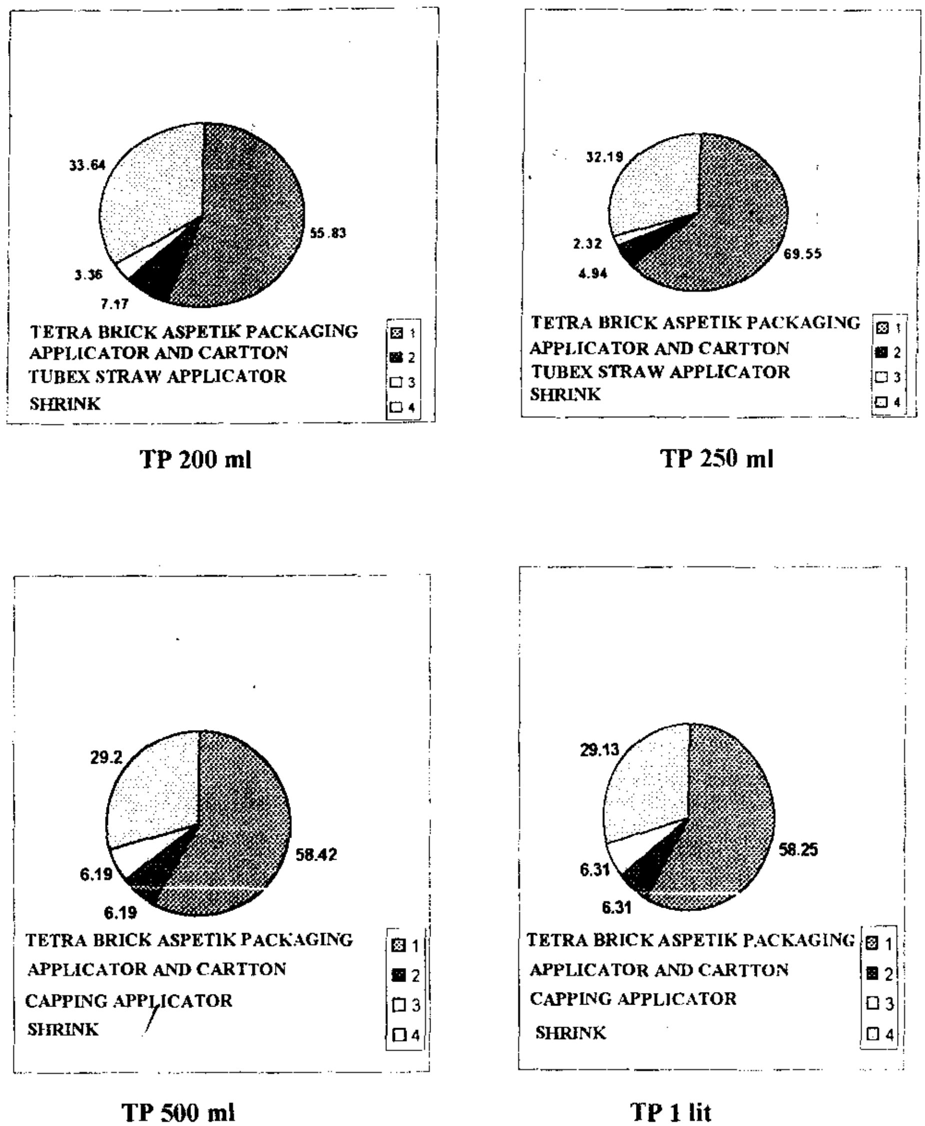


FIG. (7): The percent of energy distribution for different unit operation of milk packaging.

Energy distribution for different unit operations of packaging:

Tetra Brick Aseptic Packaging

It require an average of 82.821, 45.828, 40.811 and 28.807 MJ/ton of milk electrical energy packages volume (250, 200, 500, 1000 ml) with a percentage of 69.55, 55.83, 58.42 and 58.25% of the total energy required for milk packaging [Fig. (7) and table (2)].

Applicator and Carton

It require an average of 5.882, 5.882, 4.321 and 3.121 MJ/ton of milk electrical energy for packages (250, 200, 500 and 1000 ml) with a percentage of 4.94, 7.17, 6.19 and 6.31% of the total energy required for milk packaging [Fig. (7) and table (2)].

Tubex straw applicator

It require an average of 2.761 and 2.761 MJ/ton of milk electrical energy for packages volume (250, 200 ml) with a percentage of 2.32 and 3.36% of the total energy required for milk packaging [Fig. (7) and table (2)].

Capping applicator

It require an average of 4.321 and 3.121 MJ/ton of milk electrical energy for packages volume (500 and 1000 ml) with a percentage of 6.19 and 6.31% of the total energy required for milk packaging [Fig. (7) and table (2)].

Shrink

It require an average of 27.687, 27.607, 20.405 and 14.404 MJ/ton of milk electrical energy for packages volume (250, 200, 500, 1000 ml) with a percentage of 32.19, 33.64, 29.20 and 29.13% of the total energy required for milk packaging [Fig. (7) and table (2)].

CONCLUSIONS

1) The energy consumption by (UHT) system evaluated to be 296.400 MJ/ton of milk thermal energy and 141.265 MJ/ton electrical energy.
2) The energy consumption by (HTST) system evaluated to be 172.680 MJ/ton of milk thermal energy and 104.274 MJ/ton of milk electrical energy.
3) Milk packaging required ranges from 119.072 to 49.453 MJ/ton of milk electrical energy.
4) Milk processing percent was 77.56 for (HTST) system and 84.53% for (UHT) system whilest packaging were 22.44 and 15.47% of the total energy.

5) The (HTST) energy ratio were 7.03 while the (UHT) energy ratio were 4.85.
6) The percent of output energy to input energy was 62% of total energy and 38% of the total energy losses for cleaning, steam pipes, equipments surface, condensate steam and exhausted.

REFERENCES

Biziak, R.B.; Swartzel, K.R. and Jones, V.A. (1982): Energy evaluation of an ultra-high-temperature shell-and-tube processing system. Journal of Food Science; 47 (6): 1875.

Chandarana, D.I.; Frey, B.C.; Stewart, L.E. and Mattick, J.F. (1982): Effect of temperature and holding time on energy required to process UHT milk. ASAE PP. No. 82-6019, ASAE, St. Joseph, MI 39085.

Chandarana, D.I.; Frey, B.C.; Stewart, L.E. and Mattick, J.F. (1984): UHT milk processing-Effect on process energy requirements. Journal of Food Science. Volume 49 PP. 977-978.

Eliza, A.A. and Diakows, K.H. (2000): Solar energy in small-scale milk collection and processing W.B., Tuszynski; Chap. (2) PP.1-14.

Frey, B.C.; Chandarana, D.I.; Stewart, L.E. and Mattick, J.F. (1984): Unit process energy requirements for steam infusion UHT milk processing. Transaction of the ASAE. PP. 1956-1959).

Jimmie, J. C. and Syed, A.N. (2002): Theory and Problems of Basic Electrical Engineering. Schaum's Outline Series McGraw-Hill Book Company; Chap. (14) N.Y.

Mills, A. F. (2002): Basic Heat and mass Transfer. Prentice Hall; Chapt. (8) L. A.

Nahra, J.E. and Westhoff, D.C. (1980): Direct sterilization of heat-sensitive fluids by a free-falling-film sterillizer. Food Technology; 34 (9): 49-55, 57.

Okoth, M.W. (1990): Energy use in a large kenyan dairy factory. Dissertation Abstracts International; 51 (3) 365.

Wojdalski, J. and Malejko, B. (1984): Boiler breakdowns in dairies-principal causes and effects. Przeglad-Mleczarski. 33:4, 26-27.

Yoon, Y.H. (1983): The energy consumption status of Korean dairy processing industry. Korean Journal of Dairy Science. 5:3, 212-217.

الطاقـــة المســـتهلكة فـــــى تصنيـــــع بعـــض الأغذيــــــــة

(I) الطاقة اللازمة لتصنيع اللبن بنظامى (HTST) و (UHT)

محمد قدرى عبد الوهاب*- محمود عبد الرحمن الشاذلى* - فريد حسن بدر**

وليد محمد حنفى شحاته*

*** قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق.**

****قسم علوم الأغذية – كلية الزراعة – جامعة الزقازيق.**

استهدف هذا البحث تقييم أداء بعض الطرق المستخدمة فى تصنيع الألبان والتى تعـرف بنظامى (UHT) ، (HTST) من خلال حساب كمية الطاقة المستهلكة فى كل منهما وذلك فى مصنع جرين لاند بمدينة العاشر من رمضان.

وقد تبين من النتائج المتحصل عليها كل مما يأتى:

- استهلك نظام (UHT) طاقة حرارية قدرها (٢٩٦,٤٠٠ ميجاجول / طن لبـــن) وطاقـــة كهربية قدرها (١٤١,٢٦٥ ميجاجول/طن لبن).
- استهلك نظام (HTST) طاقة حرارية قدرها (١٧٢,٦٨٠ ميجاجول / طن لبـــن) وطاقـــة كهربية قدرها (١٠٤,٢٧٤ ميجاجول/طن لبن).
- استهلك نظام التعبئة للبن طاقة كهربية تتراوح من (٤٩,٤٥٢ ميجاجول /طن لبـــن) إلـــى (١١٩,٠٧٢ ميجاجول /طن لبن).
- استهلكت عملية التصنيع بنظامى (HTST) ، (UHT) نسبة ٧٧,٥٦% و ٨٤,٥٣% على الترتيب من الطاقة الكلية بينما استهلكت عملية التعبئة لنظامى (HTST) ، (UHT) نسبة ٢٢,٤٤% و ١٥,٤٧% على الترتيب من الطاقة الكلية.
- معدل كفاءة استخدام الطاقة لنظام (HTST) ٧,٠٣ بينما نظام (UHT) ٤,٨٥.
- نسبة الطاقة المستغلة فعليا ٦٢% من طاقة الوقود فى عمليات التصنيع بينما ٣٨% مـــــن هذه الطاقة تفقد فى عمليات التنظيف ومواسير البخار وأسطح الأجهزة والبخار المتكثـــف والعادم.