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DEVELOPMENT AND PERFORMANCE EVALUATION OF MILK PASTEURIZATION UNIT

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ABSTRACT: The main objective of the present investigation was to use the modern technological modifications for the milk pasteurization process. The original milk pasteurization unit was developed especially for the present work by adding a pneumatic regulating valve to improve its performance. The performance of the milk pasteurization unit before and after development was experimentally studied under four different heating temperatures (70, 74, 77 and 80°C), four different vapor pressures (200, 400, 600 and 800 kPa) and four different cooling temperatures (3, 4, 5 and 6°C). Evaluation of the milk pasteurization unit was carried out taking into consideration pasteurization unit productivity, heating rate, fuel consumption, energy requirements, bacteria count and final product quality. The experimental results revealed that pasteurization unit productivity (258 kg/hr.), heating rate (4.9°C/s) fuel consumption (144 l/hr.), energy requirements (1.74 kW.hr./kg) and bacteria count (35), were in the optimum region under conditions of using the developed milk pasteurization unit at 74°C heating temperature, 400 kPa vapor pressure and 4°C cooling temperature.

Key words: Pasteurization unit, pneumatic regulating valve, heating temperature, vapor pressure, cooling temperature, unit productivity, heating rate, bacteria count, fuel consumption, product quality.

INTRODUCTION

Milk occupies a leading position among the dairy food because it contain all the nutrients needed for building body and with rates conformed its needs, which gave the prescription of completion diet. Milk consists of a set of diverse elements as carbohydrate, fats, proteins, mineral salts and vitamins as well as the water which is characterized the milk by the diversity of its nutritional value but rather increased a vital value high compared to some other foods. Milk is the only food of the mammal during the first period of its life and the substances in milk provide energy and antibodies that help protect against infection.

Pasteurization is a thermal process widely used in the food and dairy industry with the objective of minimizing health hazards from pathogenic microorganisms and to prolong product shelf life. It is defined as "the heating of every particle of milk or milk product to a specific temperature for a specified period of time without allowing recontamination of that milk or milk product during the heat treatment process".

Asaad *et al.* (2012) designed a device for pasteurizing milk by ohmic heating. This device consists of raw milk tank of 25l capacity, feed pump, heat exchanger, heating tube and stainless steel electrodes that heat milk at three different voltages 220, 110 and 80 V. The device also included a holding tube of 4cm length and 1cm diameter to hold milk for 15 sec., at 72°C. It has an electric valve, delivery valve and manual valves. They found that the perfect voltage for milk pasteurization by using ohmic heating is 80V, which gave milk of good quality. The period of keeping milk in the device decreased with the increase of voltage in the ohmic heating.

Referring to the effect of the operating conditions on the milk pasteurization process, **Huppertz *et al.* (2002)** stated that high-pressure

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(HP) treatment has significant effects on many constituents of milk. HP treatment increases the pH of milk, reduces its turbidity, changes its appearance, and can reduce the rennet coagulation time of milk and increase cheese yield. **Contador *et al.* (2013)** found that high pressure processing (HPP) (at 400 or 600 MPa for 3 or 6 min) could be an alternative to holder pasteurization (HoP) (62.5°C for 30 min) for breast milk preservation in human milk banks. Treatment at 400 MPa (for 3 or 6 min) maintained the original levels of immunoglobulin's (IgM, IgA and IgG) of breast milk better than HoP. In contrast, at 600 MPa, the reduction of the original immunoglobulin's levels was similar to that following HoP. HPP and HoP destroyed most leukocytes in breast milk.

Regarding the energy requirements for operating the milk pasteurization units, **Niamsuwan *et al.* (2011)** formulated and solved an optimization problem to minimize the consumption of liquefied petroleum gas (LPG) and electricity subjecting to the defined pasteurized temperature of 76°C and maximum LPG feed rate to the burner. It has been found that the optimum LPG feed rate is 0.00125 kg/sec., to achieve the pasteurized temperature. This leads to the LPG and electricity saving of 3%. **Niamsuwan *et al.* (2013)** employed an economizer normally to perform heat recovery from hot exhaust gases to cold fluid. A newly designed economizer is devised to achieve high heat recovery in a pasteurized milk plant. Simulation results indicated that the newly designed economizer can recover the heat loss of 38% and can achieve the cost saving of 13%. **Yildirm and Genc (2015)** studied thermodynamic analysis of a milk pasteurization process assisted by geothermal energy. In this system, a water-ammonia VAC (vapor absorption cycle), a cooling section, a pasteurizer and a regenerator were used for milk pasteurization. The exergetic efficiency of the whole system was calculated as 56.81% with total exergy destruction rate of 13.66 kW. **Soufiyan and Aghbashlo (2017)** derived independently exergy efficiency and exergy destruction rate of each subcomponent of four main subsystems of plant, including steam generation, above-zero refrigeration, milk reception, pasteurization, and standardization, and yogurt drink production lines. The results indicated that the highest exergy destruction rate occurred in the boiler and compressor combination of steam generator.

However, to fully understand the effects of high pressure (HP) treatments on milk, further research is required in several areas. Therefore, the main objective of the present investigation was to use the modern technological modifications for the pasteurization process. To achieve the ultimate goal, the following criteria were taken into consideration:

- Develop the original milk pasteurization unit by adding a pneumatic regulating valve to improve its performance.
- Select the optimum operating parameters (heating temperature, vapor pressure and cooling temperature) affecting the performance of the pasteurization unit.
- Compare the final pasteurized milk quality produced from the pasteurization units before and after development.

MATERIALS AND METHODS

The main experiments were carried out during the period from April to June 2018 in Zahar dairy factory located at the new town of Salhiya, Sharkia Governorate, Egypt.

Materials

The Used Milk

The used milk was cow milk consists of around 85.3% water and 14.7% dry substance that is suspended or dissolved in the water besides total solids. The composition of the used milk is shown in Table 1.

Block Chart of the Milk Pasteurization Process

Experimental layouts and procedures mechanisms had been described in Fig. 1. However, the experimental layouts included raw milk storage, heat treatment, inter-mediate storage up to milk filling.

The Milk Pasteurization Unit Before Development

A modern milk pasteurizer, complete with equipment for operation, supervision and control of the process, is made using matching components, forming a sophisticated process unit, as shown in Fig. 2.

Table 1. The chemical composition of the used milk

Used milk	Water	Fat	Casein	Lactose	Ash	Whey protein	pH
Cow milk	85.3%	3.6%	2.8%	4.6%	0.7%	3%	6.7

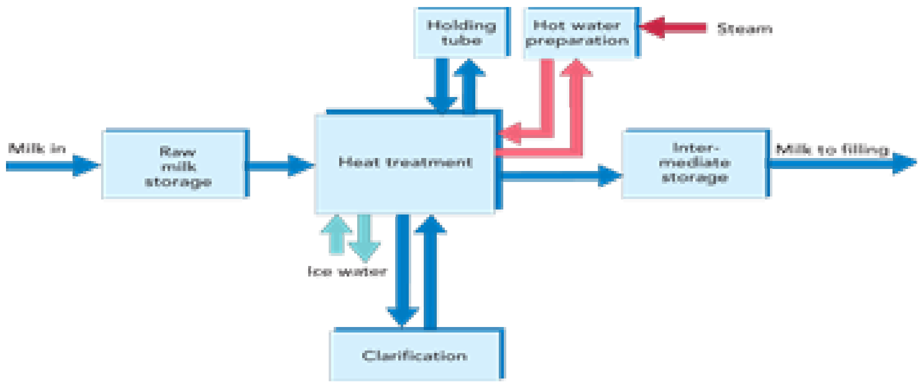
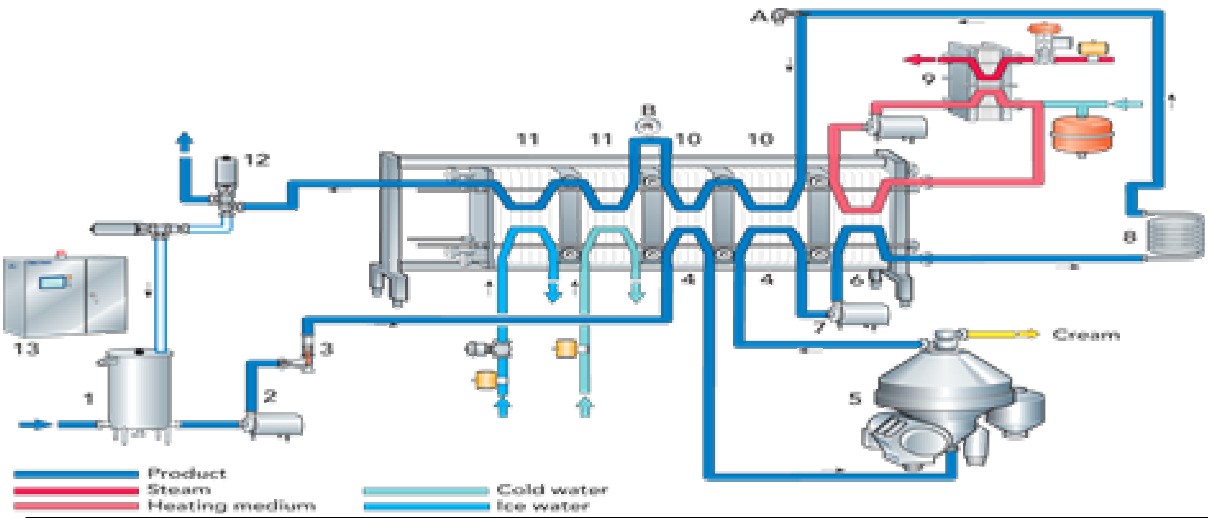


Fig. 1. Generalized block chart of the milk pasteurization process



No.	Part name	No.	Part name	No.	Part name
1	Balance tank	6	Heating section	11	Cooling section
2	Feed pump	7	Booster pump	12	Flow diversion valve
3	Flow controller	8	Holding tube	13	Control panel
4	Regenerative preheating system	9	Hot water heating system		
5	Centrifugal clarifier	10	Regenerative cooling system		

Fig. 2. The milk pasteurization unit

The complete pasteurizer plant consists of: balance tank, feed pump, flow controller, regenerative preheating section, centrifugal clarifier, pasteurizer heating section, booster pump, holding tube, hot water heating system, pasteurizer cooling section, flow diversion valve and control panel soon as the level reaches the minimum point. This signal actuates the flow diversion valve, which returns the product to the balance tank.

Balance tank

The float-controlled inlet valve regulates the flow of milk and maintains a constant level in the balance tank. As the pasteurizer must be full at all times during operation to prevent the product from burning on to the plates, the balance tank is fitted with a low-level electrode, which transmits a signal as soon as the level reaches the minimum point.

Feed pump

The centrifugal feed pump is used to supply the pasteurizer with milk from the balance tank, which provides a constant head.

Flow controller

The flow controller maintains the flow through the pasteurizer at the correct value. This guarantees stable temperature control and a constant length of the holding time for the required pasteurization effect.

Regenerative preheating section

The cold untreated milk is pumped through the preheating section. Here, it is regenerative heated with pasteurized milk, which is cooled at the same time. If the milk is to be treated at a temperature between the inlet and outlet temperatures of the regenerative section, for example clarification at 55°C, the regenerative section is divided into two sections. The first section is dimensioned so that the milk leaves at the required temperature of 55°C. After being clarified, the milk returns to the pasteurizer, which completes the regenerative preheating in the second section.

Centrifugal clarifier

The milk feeding to the clarifier is taken from the first regenerative heating section at 55°C. However, clarification at about 55°C is much more efficient, because the viscosity of the milk is lower at that temperature.

Pasteurizer heating section

Hot water is used as the heating medium to heat milk. A certain amount of heat is transferred from the heating medium to the milk so that the temperature of the latter rises and the temperature of the heating medium drop correspondingly. The heat treatment of milk is carried out in plate heat exchanger. The plate heat exchanger consists of a pack of stainless steel plates clamped in a frame.

Booster pump

A booster pump is installed in the product line after the holding section or before the heating section. The pump increases the pressure and maintains a positive differential pressure on the pasteurized product side, throughout the regenerative and cooling sections of the pasteurizer.

Holding tube

The length and size of the externally located holding tube are calculated according to the known holding time and hourly capacity of the plant and the pipe dimension, typically the same as for the pipes feeding the pasteurization plant, this tube is made of stainless steel.

Hot water heating system

The used heating medium is hot water, typically about 2–3°C higher than the required temperature of the product. Steam is delivered from the steam boiler at a pressure of 600 : 700 kPa or (6 :7 bar). This steam is used to heat water, which in turn heats the product to pasteurization temperature. The water heater is a closed system consisting of a specially designed, compact and simple cassette-type plate heat exchanger equipped with a steam-regulating valve and a steam trap.

Pasteurizer cooling system

The milk is cooled mainly by regenerative heat exchanger to about 8–9°C. Chilling the milk to 4°C for storage therefore requires a cooling medium with a temperature of about 2°C. Ice water is used for final temperature of above 3 – 4°C. The coolant is circulated from the refrigeration plant to the point of use. The flow of coolant to the pasteurizer cooling section is controlled to maintain a constant product outlet temperature. This is done by a regulating circuit consisting of a temperature transmitter in the outgoing product line, a temperature controller in the control panel and a regulating valve in the coolant supply line. The position of the regulating valve is altered by the controller in response to signals from the transmitter.The signal from the transmitter is directly proportional to the temperature of the product leaving the pasteurizer.

Flow diversion valve

A sensor after the holding cell transmits a signal to the temperature monitor. As soon as this signal falls below a pre-set value, corresponding to a specified minimum temperature, the monitor switches the flow diversion valve to divert the flow. The flow diversion valve is situated just after the holding cell. Where a booster pump is installed, the valve is located before the pump. If the temperature drops under the pre-set level, the valve diverts the flow to the balance tank and the pump stops. The flow in the regenerative and cooling sections thus comes to a standstill.

Control panel

Control loop for pressure control, consisting of transmitters and regulators.

In the pressure transmitter, the pressure of the product on a membrane is transferred to the sensor and a transmitter, which gives an electrical signal directly proportional to the product pressure. The above-mentioned pressure transmitter is also used to measure the level in the balance tank. Installed in the bottom of a tank, it senses the static pressure of the liquid column above the diaphragm. This pressure is proportional to the height of the liquid. A signal is transmitted to an instrument, which indicates the level.

The temperature transmitter utilize the fact that the electrical resistance of metals varies with temperature in a characteristic manner.

Regulators

A regulator is a device that continuously compares the measured value with a reference or pre-set (set point) value.

Any differential causes the regulator to transmit a corrective signal to the regulating unit, which then adjusts its setting accordingly.

The Milk Pasteurization Unit After Development

The modern milk pasteurizer was developed by adding a pneumatic regulating valve to improve its performance.

The developed pasteurizer unit consists of: balance tank, feed pump, flow controller, regenerative preheating section, centrifugal clarifier, pasteurizer heating section, booster pump, holding tube, hot water heating system, pasteurizer cooling section, flow diversion valve and control panel. All the developed unit components are the same as described with the pasteurizer unit before development except for the pneumatic regulating valve.

The pneumatic regulating valve

A pneumatic regulating valve is built around a body with a seat for the plug, which is attached to the lower end of the regulating stem (Fig. 3). The stem is operated between the open and closed positions by differential pressure between the upper and lower sides of the piston. When the pressure is higher than the lower side, the piston moves upwards, lifting the plug from its seat.

A higher pressure on top of the piston closes the valve. Actuation is essentially as follows: a pneumatic signal from a controller is supplied to a proportioning device, a positioner at the top of the valve.

The positioner ensures that the position of the plug, in relation to the seat, always is proportional to the regulating signal. When the signal corresponds to the pre-set value, the positioner balances the pressures on either side (the upper and lower sides of the piston) of the piston so that the position of the plug remains constant. In this balanced condition the pressure drop over the valve is exactly what is required, and the measured value registered by the transmitter coincides with the pre-set value. If the product pressure drops, the transmitter reduces its signal to the regulator. As the measured value now no longer coincides with the pre-set value, the regulator reacts by increasing its signal to the valve actuator. The positioner then increases the pressure on the upper side of the piston, moving the plug towards the seat. The resulting increase in the

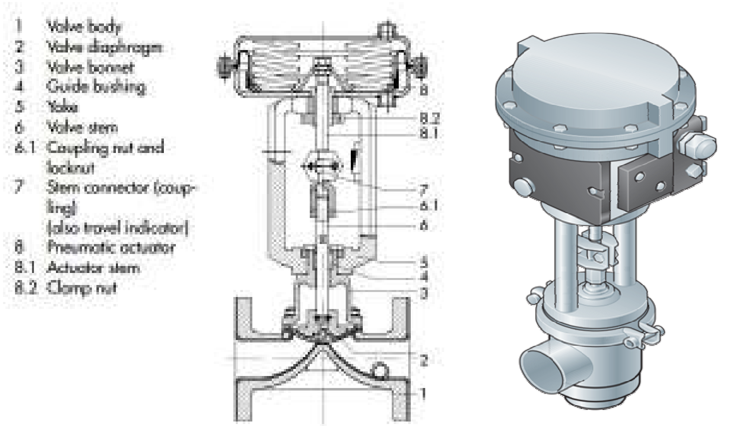


Fig. 3. The pneumatic regulating valve

valve flow resistance increases the product pressure and the reverse cycle of operations is initiated, retarding the downward movement of the piston. When the pressure in the line has reached the pre-set value, the positioner holds the valve piston in balance.

Methods

The main experiments were carried out to develop and evaluate the performance of the milk pasteurization unit.

Experimental Conditions

The performance of the milk pasteurization unit was experimentally measured under the following parameters:

- Four different heating temperatures (70, 74, 77 and 80°C).
- Four different vapor pressures (200, 400, 600 and 800 kPa).
- Four different cooling temperatures (3, 4, 5 and 6°C)

During the experiments, time of heating is taken constant at 15 sec., water discharged for the heating unit is taken constant at 50 l/hr and water discharge for the cooling unit is taken constant at 10 m^3/hr.

Measurements and Determinations

The performance of the milk pasteurization unit was evaluated taking into consideration the following indicators:

Pasteurized milk productivity

The unit productivity was determined by the total pasteurized milk out of the unit per hour **(Asaad *et al.,* 2012).**

$$PMP = Q/ t \qquad (1)$$

Where:

PMP - Pasteurized milk productivity, kg/hr.,

Q - Total pasteurized milk, kg,

t - Time required to pasteurized milk, hr.

Heating rate

The heating rate was determined by dividing the heating temperature by the time required to reach to that temperature **(Asaad *et al.,* 2012).**

$$HR = T / t \qquad (2)$$

Where:

HR – Heating rate, °C/sec.,

T - Heating temperature, °C,

t-Time required to reach to heating temperature, sec.

Fuel consumption

During the operation, fuel consumption was determined by measuring the fuel required to refill the fuel tank after the working period by means of graduated glass cylinder it was calculated by using the following equation **(Asaad *et al.,* 2012):**

$$Fc = V_f / t \qquad (3)$$

Where:

Fc - Fuel consumption, l/hr.,

V_f - Volume of consumed fuel, l,

t - Time of operation, hr.

Energy requirements

Energy requirements (ER) can be calculated using the following formula:

ER (kW.hr./kg) = P (kW) / PMP (kg/hr.)

Required power was estimated from the fuel consumed during the feed distribution operation using the following formula **(Hunt, 1983):**

$$P = \left[F_c \left(\frac{1}{3600} \right) P_E \times \text{L.C.V.} \times \eta_{th} \times \eta_m \times \frac{427}{75 \times 1.36} \right] \quad (4)$$

Where:

P – Required power, kW,

F - Fuel consumption, l/hr.,

PE - Density of fuel (kg/l), (for diesel fuel 0.85)

LCV - Calorific value of fuel, (10000 kcal/kg)

η_{th} - Thermal efficiency of the engine, (for diesel engine, 35%)

427- Thermo-mechanical equivalent, (kg. m/kcal)

η_m - Mechanical efficiency of engine, (for diesel engine, 85%)

Bacteria count

The percentage of bacteria count in raw milk and pasteurized milk was determined by Direct Microscope Bacteria Count test **(Jurjen *et al.*, 2009).** A microscope is calibrated so that the exact area of the microscopic field is known; a milk sample is spread, allowed to dry and stained with a suitable dye. The average number of bacteria per microscopic field is determined after examining between 5 and 60 fields.

Measurement of Milk Quality

Final pasteurized milk quality was measured in terms of chemical properties for both milk pasteurization units before and after development. Random samples of pasteurized milk were taken to obtain the product quality. Milk samples were analyzed in the laboratory of Zahar dairy factory located at the new town of Salhiya, Sharkia Governorate, Egypt.

Final pasteurized milk quality can be measured as follows:

Fat percentage

The percentage of fat in the pasteurized milk and raw milk was determined by Gerber test **(Jurjen *et al.*, 2009)**. The test is a volumetric method in which fat is separated from milk by centrifugal force. Sulphuric acid is used to dissolve the protein that forms the membrane around the fat (fat globules) and amyl alcohol is added to improve the separation of fat from other solids.

Protein content

The protein content in the pasteurized milk and raw milk was determined by the protein test **(Jurjen *et al.*, 2009)**. When formaldehyde is added to milk, the free amino groups of the protein react with the carbonyl groups of formaldehyde causing the milk to become acidic. The acidity developed is related to the amount of protein present, which may be measured by titrating with sodium hydroxide (Na OH) using phenolphthalein as an indicator.

Lactose, minerals and vitamins

The percentage of lactose, minerals and vitamins found in raw and pasteurized milk was determined by solid material test **(Jurjen *et al.*, 2009)** by the equation:

$$TS (\%) = 0.25 (L) + 1.22 \text{ fat} (\%) + 0.72 \quad (5)$$

(L = Lactometer reading in degrees)

The Totals Solids (TS) content in milk is the mass percentage of substances in the milk, comprising fat, protein, lactose, minerals and vitamins. The TS content of milk can either be measured by using estimation from the lactometer reading, by drying the milk and weighing the solids or by using rapid Automatic milk analysers (AMAs). Solids-not-fat (SNF) in milk comprises protein lactose, minerals and vitamins.

Acidity and pH

Acidity and pH of raw milk and pasteurized milk was determined by pH- meter **(Jurjen *et al.*, 2009).** A pH meter depends on the potential difference between two electrodes when they are in contact with a test sample. One electrode called a reference electrode (a glass electrode) independent of the pH of the milk is connected to an electrode whose potential is proportional to the pH of the milk (a calomel electrode). The pH of the milk depends on the hydrogen ion concentration in the milk. A pH meter measures the current produced by the difference in potential between the two electrodes.

RESULTS AND DISCUSSION

The discussion will cover the obtained results under the following heads:

Effect of Some Operating Parameters on Pasteurized Milk Productivity

Results in Figs. 4 and 5 show that the milk productivity values of the pasteurization unit after development are higher than values of the pasteurization unit before development due to the presence of the pneumatic regulating valve, which help in balancing the pressure that help in controlling temperature. The pasteurized milk productivity values reached their optimum values of 230 and 258 kg/hr., for pasteurization units before and after development, respectively under 74°C heating temperature and 400 kPa vapor pressure. Regarding the effect of heating temperature on pasteurized milk productivity, results in Fig. 4 show that heating temperature has a little effect on pasteurized milk productivity, because pasteurization operation was successfully done under the mentioned rate of temperatures (70, 74, 77 and 80°C).

Relating to the effect of vapor pressure on pasteurized milk productivity, results in Fig. 5 show that increasing vapor pressure from 200 to 800 kPa, increased pasteurized milk productivity from 220 to 300 and from 230 to 344 kg/hr., for pasteurization units before and after development, respectively under 74°C heating temperature. This increase is attributed to that increasing vapor pressure strongly decreased the time spent for heating milk resulting in an increase in productivity.

As to the effect of cooling temperature on the milk productivity, experiments showed that cooling temperature has no effect on the pasteurized milk productivity as it was kept constant at 4°C during the experiments.

Effect of Some Operating Parameters on Heating Rate

Concerning the effect of heating temperature on the heating rate, obtained data in Fig. 6 show that the heating rate values of the pasteurization unit after development are higher than values of the pasteurization unit before development due to the presence of the pneumatic regulating valve, which help in balancing the pressure and as a result avoid any variation in the heating temperature.

The heating rate values reached their optimum values of 4.7 and 4.9°C/hr., for pasteurization units before and after development, respectively under 74°C heating temperature and 400 kPa vapor pressure. Results also showed that increasing heating temperature from 70 to 80°C, increased heating rate from 4 to 5 and from 4.5 to 5.2°C/hr., for pasteurization units before and after development respectively under 400 kPa vapor pressure.

As to the effect of both vapor pressure and cooling temperature on the heating rate, experiments showed that both vapor pressure and cooling temperature have no effect on the heating rate as they were kept constant at 400 kPa and 4°C during the experiments.

Effect of Some Operating Parameters on Fuel Consumption

Obtained results in Figs. 7 and 8 show that the fuel consumption values of the pasteurization unit after development are lower than the pasteurization unit before development The fuel consumption values reached their optimum values of 147 and 144 l/hr., for pasteurization units before and after development, respectively under 74°C heating temperature and 400 kPa vapor pressure.

Considering the effect of heating temperature on fuel consumption, results in Fig. 7 show that increasing heating temperature from 70 to 80°C, increased fuel consumption from 134 to 164 l/hr., and from 132.5 to 161.2 l/hr for pasteurization units before and after development, respectively under 400 kPa vapor pressure. This increase is attributed to that, heating milk at high temperatures required more fuel to accomplish the operation.

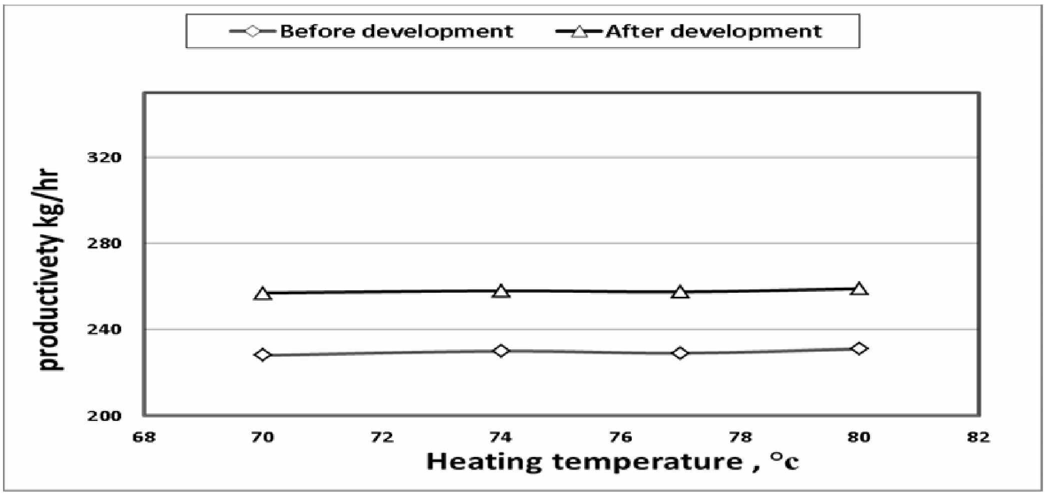


Fig. 4. Effect of heating temperature on pasteurized milk productivity

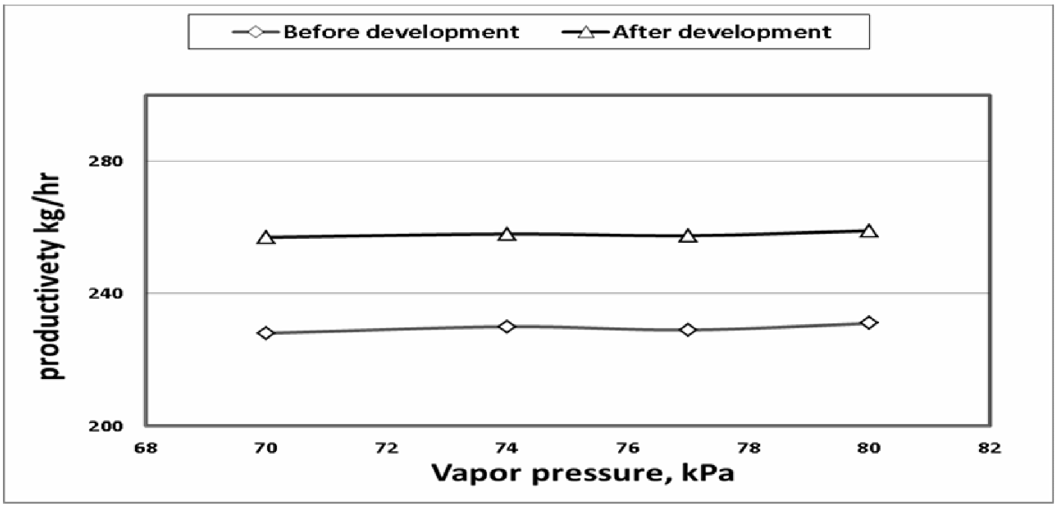


Fig. 5. Effect of vapor pressure on pasteurized milk productivity

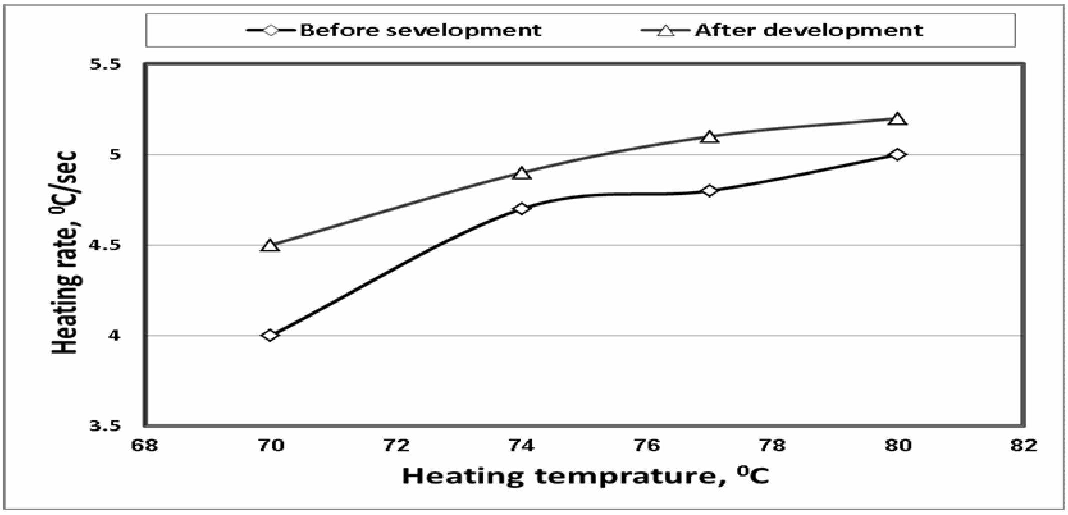


Fig. 6. Effect of heating temperature on heating rate

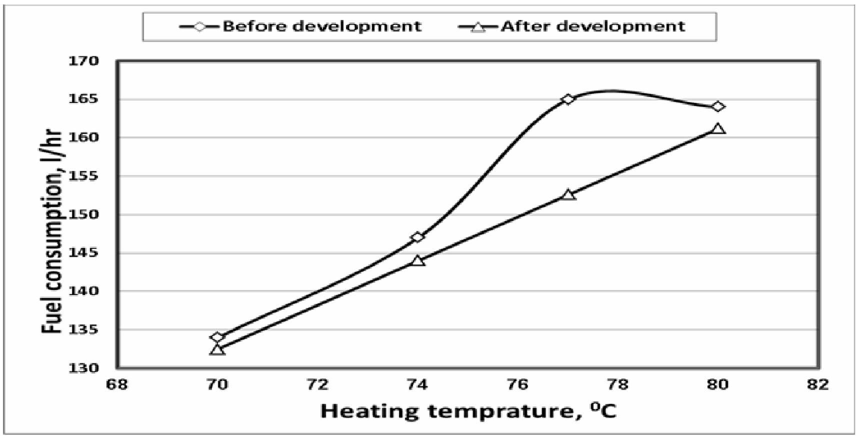


Fig. 7. Effect of heating temperature on fuel consumption

As to the effect of vapor pressure on the fuel consumption, results in Fig. 8 show that the fuel consumption of the pasteurization unit after development are lower than the pasteurization unit before development due to the presence of the pneumatic regulating valve, which help in balancing the pressure. Results showed that increasing vapor pressure from 200 to 800 kPa, increased fuel consumption from 147 to 178 l/hr and from 140 to 172 l/hr for pasteurization units before and after development, respectively under 74°C heating temperature. This increase is attributed to that, heating milk at high vapor pressures required more fuel to accomplish the operation.

As to the effect of cooling temperature on the required power, experiments showed that cooling temperature had no effect on the required power as it was kept constant at 4°C during the experiments.

Effect of Some Operating Parameters on Energy Requirements

Obtained results in Figs. 9 and 10 show that the energy requirements values of the pasteurization unit after development are lower than the pasteurization unit before development. The energy requirements values reached their optimum values of 2.0 and1.74 kW.hr./kg for pasteurization units before and after development, respectively under 74°C heating temperature and 400 kPa vapor pressure.

Regarding the effect of heating temperature on the energy requirements, obtained results in Fig. 9 show that increasing heating temperature from 70 to 80°C, increased energy requirements from 1.96 to 2.1 kW.hr/kg and from 1.72 to 1.8 kW.hr/kg for pasteurization units before and after development, respectively under vapor pressure of 400 kPa. This increase is attributed to that the increase in fuel consumption is pronounced with accompanied little increase in productivity.

As to the effect of vapor pressure on the energy requirements, results in Fig. 10 show that increasing vapor pressure from 200 to 400 kPa, decreased energy requirements from 2.1 to 2.0 and from 1.8 to 1.74 kW.hr./kg for pasteurization units before and after development, respectively under heating temperature of 74°C and 400 kPa vapor pressure. Any further increase in vapor pressure more than 400 up to 800 kPa, tends to increase energy requirements from 2.0 to 2.25 and from 1.74 to 1.77 kW.hr./kg under the same previous conditions. The decrease in energy by increasing vapor pressure from 200 to 400 kPa is attributed to the increase of productivity. While the increase in energy requirements by increasing vapor pressure from 400 to 800 kPa is attributed to that, the increase in fuel consumption is pronounced comparing to the accompanied increase in productivity.

As to the effect of cooling temperature on the energy requirements, experiments showed that cooling temperature had no effect on the energy requirements as it was kept constant at 4°C during the experiments.

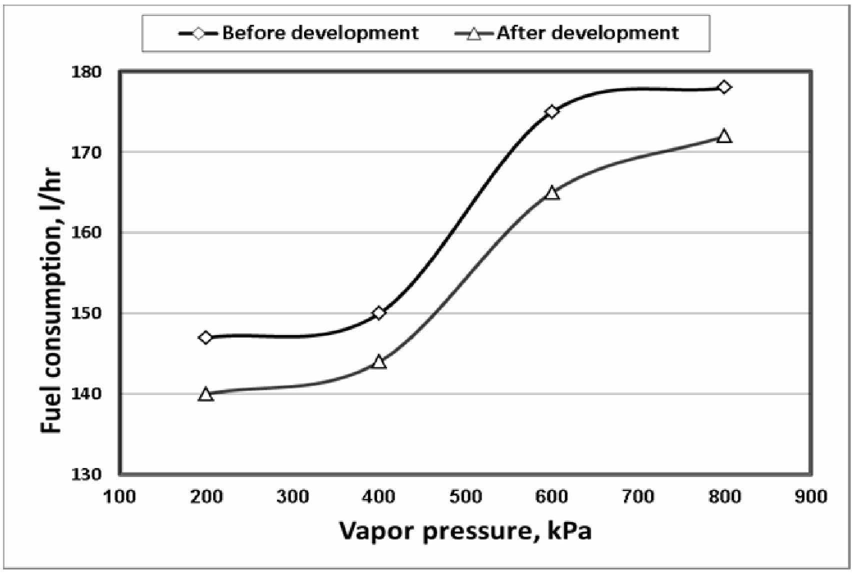


Fig. 8. Effect of vapor pressure on the fuel consumption

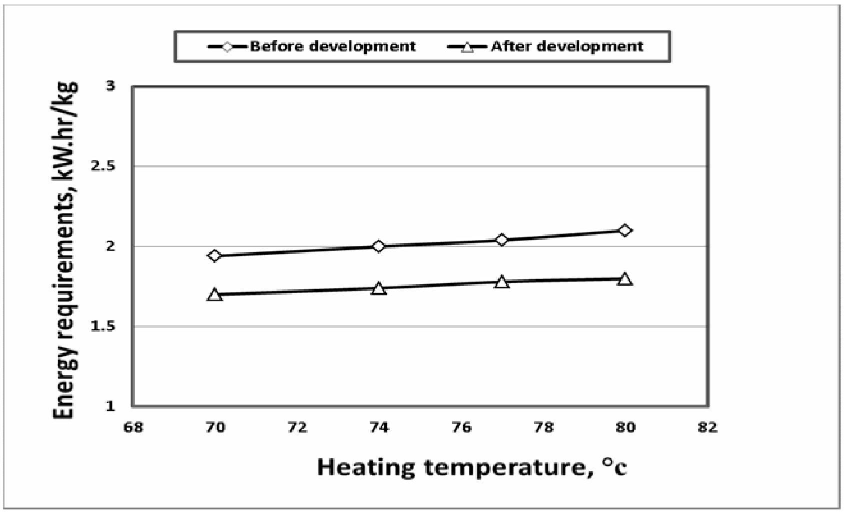


Fig. 9. Effect of heating temperature on the energy requirements

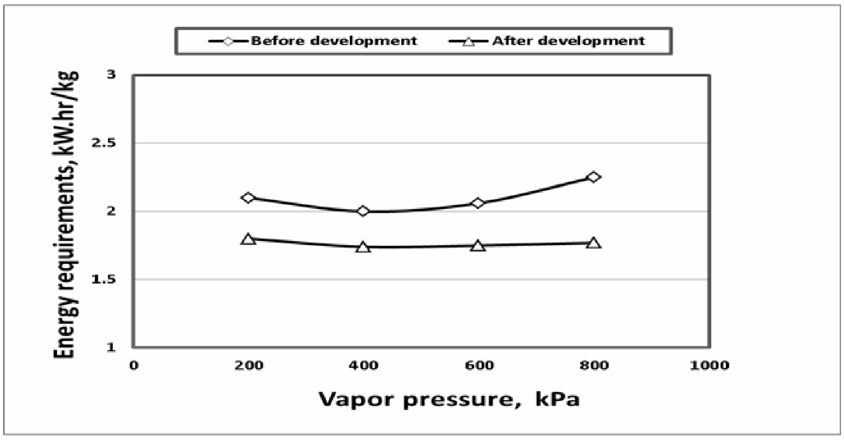


Fig. 10. Effect of vapor pressure on the energy requirements

Effect of Some Operating Parameters on Bacteria Count

Obtained results in Figs. 11 and 12 show that the bacteria count values of the pasteurization unit after development are lower than the pasteurization unit before development due to the presence of the pneumatic regulating valve, which help in balancing the pressure and as a result avoid any variation in the heating temperature. The bacteria count values reached their optimum values of 40 and 25 for pasteurization units before and after development, respectively under 74°C heating temperature and 4°C cooling temperature While it reached up to 35000 in raw milk.

With regard to the effect of heating temperature on bacteria count, results in Fig. 11 show that increasing heating temperature from 70 to 80°C, decreased bacteria count from 50 to 30 and from 35 to 20 for pasteurization units before and after development, respectively under cooling temperature of 4°C. The increase in heating temperature decreased bacteria count as high heating helps in purifying milk from bacteria.

As to the effect of cooling temperature on the bacteria count, results in Fig. 12 show that increasing cooling temperature from 2 to 8°C, increased bacteria count from 27 to 80 and from 25 to 70 for pasteurization units before and after development, respectively under heating temperature of 74°C. The increase in bacteria count by increasing cooling temperature is due to that high temperatures give the opportunity of good environment for bacteria.

As to the effect of vapor pressure on bacteria count, experiments showed that vapor pressure had no effect on bacteria count as it was kept constant at 400 kPa during the experiments.

Final Pasteurized Milk Quality

In order to ensure a consistent, high quality product that is safe for all uses, it is important to develop quality guidelines for milk that is sold or given away. Milk must be free of harmful foreign matter that may cause harm or injury to humans during or resulting from intended use. results obtained in Table 2 show some chemical properties of the raw milk and milk pasteurized by both pasteurization units before and after development.

The obtained results in Table 2 show that the final milk quality for pasteurized milk by the developed unit and that, which pasteurized using the undeveloped unit, is approximately similar. While bad quality, far from quality guidelines, is obtained with the raw milk. The same table shows that fat, protein and lactose are higher in pasteurized milk by the developed unit comparing to pasteurized milk by the undeveloped unit.

From this point of view, it is noticed that pasteurized milk using the pasteurization unit after development improves the quality of the produced milk by removing unwanted objects such as bacteria and other trash.

Conclusion

The main objective of the present investigation was to use the modern technological modifications for the milk pasteurization process. The original milk pasteurization unit was developed by adding a pneumatic regulating valve to improve its performance. The experimental results revealed that pasteurization unit productivity (258 kg/hr.), heating rate (4.9^{o}C/sec.), fuel consumption (144 l/hr.), energy requirements (1.74 kW.hr./kg) and bacteria count (35), were in the optimum region under the following conditions:

- Using the developed unit for the milk pasteurization process.
- Adjusting the milk pasteurization unit at 74^{o}C heating temperature and 400 kPa vapor pressure.
- Adjusting the pasteurizer cooling system at 4^{o}C cooling temperature.

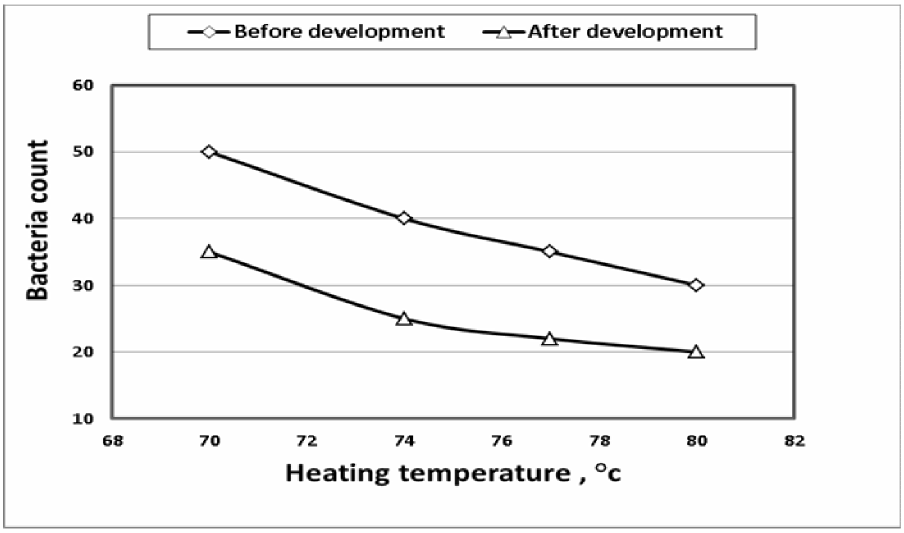


Fig. 11. Effect of heating temperature on bacteria count

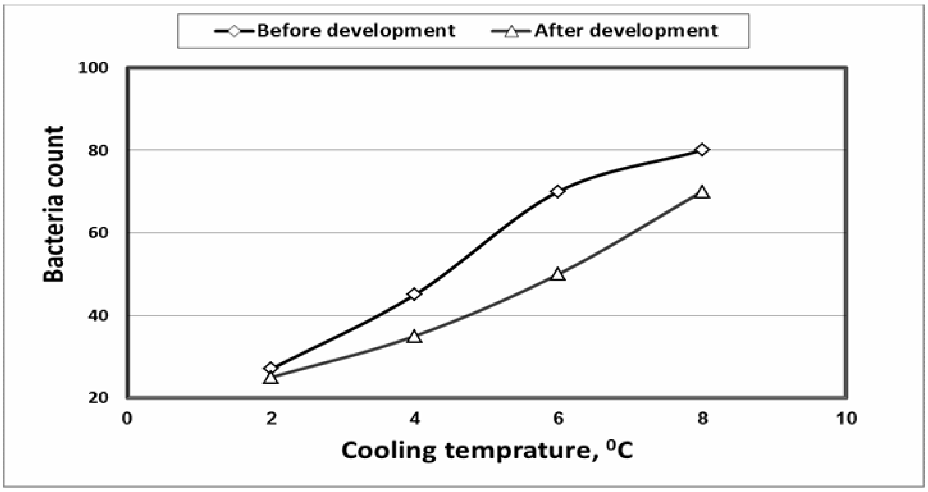


Fig. 12. Effect of cooling temperature on bacteria count

Table 2. The chemical properties of final pasteurized milk quality

Chemical property	Raw milk	Pasteurized milk by pasteurization unit before development				Pasteurized milk by pasteurization unit after development			
		Heating temperatures (°C)				Heating temperatures (°C)			
		70	74	77	80	70	74	77	80
Fat	3.6%	3.4	3.4	3.4	3.35	3.5	3.5	3.52	3.45
Protein	3.0%	2.9	2.9	2.9	2.9	3.0	2.95	2.92	2.9
Lactose	32%	31.3	31.2	31	31	32	31.5	31.3	31
pH	6.7	6.6	6.5	6.5	6.45	6.6	6.6	6.56	6.5
Acidity	14,5	17	17	17	17	15	15	16	17

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تطـــويـــر وتقييـــم أداء وحـــدة بســـترة اللبــــن

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احتلت الألبان موقع الصدارة بين المواد الغذائية نظرا لاحتوائها على جميع العناصر الغذائية اللازمة لبناء الجسم وبمعدلات تتواءم مع احتياجاته مما أعطاها صفة الاكتمال الغذائي ليعتمد عليه الإنسان منذ بدء حياته حتى فترة قد تصل إلى عام من عمره كغذاء أوحد، ومن أهم المعاملات الحرارية المتبعة في معامل الألبان هي البسترة والتعقيم. لذا فقد اتجه هذا البحث الى محاولة تطوير وحدة بسترة اللبن بغرض رفع جودة المنتج النهائي وكذلك تحديد القيم المثلى لعوامل التشغيل (درجة حرارة التسخين، ضغط البخار ودرجة حرارة التبريد) التي تؤثر على أداء وحدة البسترة من حيث الإنتاجية ومعدل التسخين واحتياجات القدرة والطاقة وكذلك جودة المنتج النهائي، تم تنفيذ التجارب العملية بمصنع الزهار للألبان بمدينة الصالحية الجديدة بمحافظة الشرقية خلال الفترة من ابريل إلى يونيو عام ٢٠١٨ حيث تم تطوير وحدة بسترة اللبن بغرض رفع جودة المنتج النهائي وذلك بإضافة صمام منظم للضغط لتحسين أدائها، أظهرت النتائج التجريبية أن القيم المثلى لكل من إنتاجية وحدة البسترة (٢٥٨ كجم/ساعة) ومعدل التسخين (٤,٩ م°/ثانية) واستهلاك الوقود (١٤٤ لتر/ساعة) والطاقة المستهلكة (١,٧٤ كيلووات.ساعة/كجم) والعد البكتيري (٣٥) تحدث تحت ظروف التشغيل الآتية: استخدام وحدة البسترة المطورة لإجراء عملية بسترة اللبن، ضبط وحدة بسترة اللبن عند درجة حرارة تسخين ٧٤ م° وضغط البخار عند ٤٠٠ كيلو باسكال (٤ بار) وضبط وحدة تبريد اللبن عند درجة حرارة تبريد ٤م°.

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