

Technical aspect method to concentrate Whey milk

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Abstract

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This study aims to fabricate technical spray unit to concentrate the whey to use as byproduct by utilization of the local material. The experiment and fabricated technical spray system was manufactured using the local materials to concentrate the whey under laboratory conditions in work shop and Laboratory of the Agricultural Engineering Department at Kafrelsheikh University. The whey was collected from Dairy lab, Faculty of Agriculture, Kafrelsheikh University. The fabricated concentrated unit and built as follows: Main tank from steel, Manometer for air and whey, pneumatic nozzle atomizer, electrical heater, valves, heat sensors PT100, compressor, PC, collector tank and whey pump. Thermal wool was used to isolate of the main container from outside. The pneumatic nozzle atomizer (Lechler 156.000.35.11) was set up in the top of main container. The electric heater was adopted in the bottom of the main container. The PT 100 heat sensor was put and fixed in inner and outer main container. The pneumatic nozzle was constructed with the whey pump in one side and connected with air compressor in other side of nozzle. The valves of whey and air valve were used to obtain the different liquid pressure (whey) and air pressure.

The energy consumed was 0.0325 kW.h, 0.0341 kW.h and 0.0348 kW.h for operating air compressor pressure 0.2 MPa, 0.3 MPa and 0.4 MPa respectively. On the other hand, the specific energy requirement to concentrate one liter of whey was 0.325 kW h l⁻¹, 0.272 kW.h l⁻¹ and 0.139 kW h l⁻¹ at operating air compressor pressure 0.2 MPa, 0.3 MPa and 0.4 MPa respectively. The maximum whey concentration produced from the spray concentrated unit or dryer at full open valve and input concentration 10% solution were 37.5 %, 37.5% and 39.97% at operating pressure 0.2 MPa, 0.3 MPa and 0.4 MPa operating and at temperature of the spray concentrated unit or dryer 66.5°C, 69.5°C and 72.5°C respectively. The results revealed that increasing the operating pressure and temperature of the spray concentrated unit or dryer tends to increase the whey concentration produced from the fabricated spray concentrated unit or dryer for different input concentration 5 %, 7%, 10% and chaise collected whey at full and half open valve of the liquid (flow rate, 0.1 l min⁻¹, 0.125 l min⁻¹ and 0.25 l min⁻¹). On the other hand, the maximum whey concentration produced from the spray concentrated unit or dryer at half open valve and input concentration 10% solution were 38.31%, 39.75% and 40.02% at operating pressure 0.2 MPa, 0.3 MPa and 0.4 MPa respectively.

Keywords: spray; whey; concentration

Introduction

The dairy industry generates large quantities of by-products rich in whey proteins and lactose. The two byproducts that stand out are cheese whey and whey permeates (Mollea et al., 2013, Gannoun et al. 2008). Cheese whey is the main

pollutant in dairy wastewaters from cheese production. However, cheese whey has a high nutritional value, is a source of biologically valuable proteins and is also rich in vitamins, mainly riboflavin, and minerals (Carvalho et al., 2013 and Gaucher et al 2008). Several methods have been developed to utilize this by-product. One way to reuse cheese whey is

through ultrafiltration. This process is used to separate cheese whey proteins and produces whey retentive, which can be subjected to drying, thus generating a concentrated dryer product known as whey protein concentrate (WPC). This process also generates another by-product, Whey permeate, which is rich in lactose, minerals and vitamins. If whey permeate is discarded prior to any treatment, it causes extensive environmental damage. However, if the permeate is incorporated into the dairy wastewater, it increases the organic matter content, and the treatment becomes too expensive, particularly for small cheese plants (Mollea et al., 2013). Thus, it is necessary to investigate new and value-added applications for dairy wastes to enhance their utilization and to decrease the amount of whey discarded as waste. One of the most nutrient dairy products is whey. Whey or milk serum contains a large amount of required body nutrition, including about 4.5 % (weight over volume, or w/v) lactose, 0.8 % (w/v) protein, 1% (w/v) salt, and 0.1–0.8 % (w/v) lactic acid.

Whey is transparent, yellowish–green and has a slight tart flavor (Grba et al., 2002; Farizoglu et al., 2007). During the production of cheese, milk curdles and subsequently coagulates. Through this process, the hard part (casein) and the liquid part (whey) separate from each other, such that the liquid part includes nearly half of the milk solid ingredients (Keramat et al., 2007; Etzel, 2004). In the process of producing one kilogram of cheese, about eight kilograms of whey are obtained. Although whey constitutes a considerable portion, since its nutrition facts are not well-known, it is wasted as wastewater (Estrella et al., 2004; De Wit, 2001). Many products can be derived from whey through various processes and technologies. Among popular whey products are condensed whey, dried whey, modified dry whey, whey protein concentrates and isolates, as well as lactose (crystallized and dried). There are also many other secondary and tertiary products that can be derived from whey. Bulk density is important for packaging and shipping considerations. Particle size distribution is having Factors influencing the properties of fruit juice powder produced by spray dry technique. Spray drying is a technique widely used in the food industry to produce food powder due to its effectiveness under the optimum condition (Cano-Chuca et al., 2005; Jittanit et al., 2010; Casal et al., 2006; Bimbenet et al., 2002). The spray drying parameters such as inlet temperature, air flow rate, feed flow rate, atomizer speed, types of carrier agent and their concentration are influencing as particle size, bulk density, moisture content, yield and hygroscopicity in spray dried foods (Chegini & Ghobadian, 2005; Chegini & Ghobadian, 2007; Yousefi et al., 2011 and Beolchini et al., 2004). Walton (2000) reported, the increase of drying air temperature generally causes the decrease in bulk, particle

density and provides the greater tendency to the particles to hollow. In addition, the particle size was affected by inlet temperature as reported by Tonon et al. (2011). The use of higher inlet air temperature leads to the production of larger particles and causes the higher swelling. The similar finding was also obtained by other authors (Chegini & Ghobadian, 2005; Nijdam & Langrish, 2006; Reineccius, 2001). Reineccius (2001) reported, drying at higher temperatures results in faster drying rates, which was leading to the early formation of a structure and that did not allow the particles to shrink during drying. When the inlet air temperature is low, the particle remains more shrunk and smaller. Nijdam & Langrish (2006) were obtained the similar results in the production of milk powder at 120 and 200.

The increase of inlet temperatures has given the higher process yield and it was due to the greater efficiency of heat and mass transfer processes occurring when higher inlet air temperatures were used. This is in accordance with the amaranthus betacyanin pigments by Cai & Corke (2000). On the other hand, the increase of inlet air temperature has reduced the yield and it might be caused by melting of the powder and cohesion wall and therefore the amount of powder production and yield was reduced (Chegini & Ghobadian, 2007; Dolinsky et al., 2000; Dolinsky, 2001). A lower drying air flow rate causes an increase in the product halting time in drying chamber and enforces the circulatory effects (Goula & Adamopoulos, 2004; Oakley & Bahu, 2000, Panesar et al. 2007; Murugeson et al. 2011). The increased residence time led to the greater degree of moisture removal. As a result, an increase of the drying air flow rate, decrease the residence time of the product in the drying chamber and it leads to have higher moisture contents. In addition, the effect of drying air flow rate of powder bulk density depends on its effect on moisture content due to the sticky nature of the product. The higher moisture content in the powder leads to stick together and consequently leaving more interspaces between them and it results the larger bulk volume. Therefore, the raise of air flow rate leads to an increase of moisture content in the powder and decreased in powder bulk density. The Fluidized Spray Concentrated unit or dryer combines spray drying and fluid bed drying technologies and offer excellent product flexibility and excellent thermal efficiency. Sticky products can be dried successfully, and the concept is ideal for drying heat sensitive products, and improved aroma retention is accomplished.

Droplet drying: moisture evaporation

Vehring et al. (2007) illustrated that the aerosol droplets contact with the drying medium within the chamber, they undergo evaporation and solute condensation, resulting in

solvent removal. This phenomenon reflects a heat and mass balance problem driven by the difference between the solvent's vapor pressure and its partial pressure toward a gas phase. Thus, the hot gas temperature triggers a heat exchange from it to the droplets, whereas the vapor pressure difference causes a moisture transfer in the opposite direction. Anandharamakrishnan (2015) presented the drying kinetics of the spray-drying process comprise several steps with different durations and specific events. Immediately upon gas-droplet contact, heat transfer from the gas to the droplet causes an increase of droplet's temperature, from its initial temperature (T_i) to a constant value, the equilibrium evaporation temperature (T_{eq}). Handscomb et al. (2009) the drying process proceeds at a constant evaporation rate, that is, a fast water diffusion from the droplet core to its surface allows a constant moisture removal.

Thus, the droplet surface remains sufficiently cool and saturated with moisture, keeping its temperature constant at the wet-bulb temperature. Wet-bulb temperature is the name given to the temperature of the gas when it gets saturated with vapor from the liquid. This is the lowest temperature that the drying gas can reach due to the evaporative cooling phenomenon, that is, the gas is cooled as it spends latent heat of vaporization. Moisture evaporation occurs at a constant rate until a critical value of the droplet water content is reached. In other words, when the solute dissolved in the liquid reaches almost its saturation, a thin shell (also known as crust) is formed at the droplet surface, and, as a result, evaporation slows down and becomes dependent on the water diffusion rate through such surface shell (Ortega-Rivas et al., 2006, Minhalma et al., 2007; Maury et al., 2005). This marks the beginning of the drying kinetics' falling rate period, being immediately noticeable an increasing particle temperature. When droplet temperature reaches the moisture boiling point, vaporization takes places, a transition which requires a large amount of energy. This means there is no longer a sensible heating of the particles and thus, the drying process proceeds driven by external heat transfer from the air to the particle. Once again, there is an increase of particle temperature until it becomes equal to that of the surrounding gas, marking the end of the drying process (Handscomb et al., 2009).

Objectives

The objective in the current research was fabricated spray dryer unit to concentrate the whey by utilization of the local material. We will go to concentrate the whey not drying. As well as, reduce the pollutant in dairy wastewaters. However, whey has a high nutritional value, is a source of biologically valuable proteins and is also rich in vitamins, mainly riboflavin, and minerals that may be used as byproduct.

Materials and Methods

The fabricated spray concentrated unit or dryer unit was constructed and fabricated in the laboratory of agricultural engineering department, faculty of agriculture, Kafrelsheikh University. It is consisting of the following component: Main tank, manometer for air and whey, pneumatic nozzle, electrical heater, valves, heat sensors PT100, compressor, PVC collector tank and whey pump as shown in Figure 1.

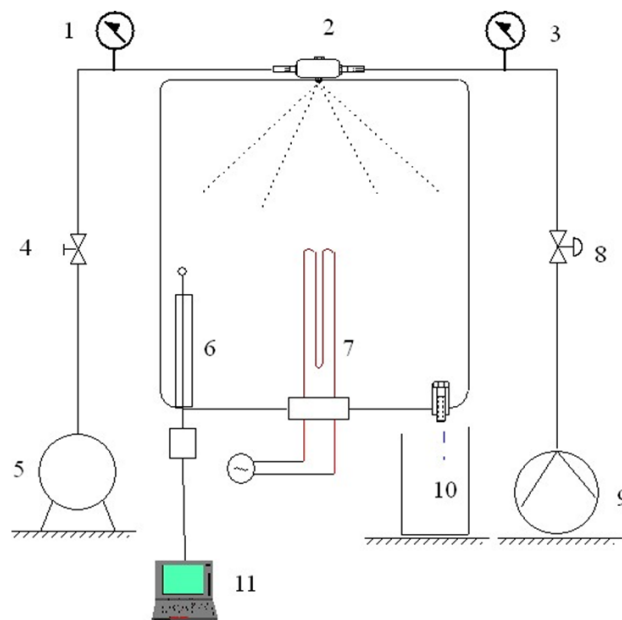


Fig. 1. Diagram of spray drying system and their component

Legend: 1 – liquid (whey) manometer 2 – Air induction nozzle 3 – Air pressure manometer 4 – Whey valve 5 – Whey pump 6 – PT heat sensor 7 – Electric heater 8 – Air valves 9 – Compressor

The main container made from stainless steel and their length was 30 cm with diameter 37 cm. The diameter of the upper opening inlet was 3 cm and the pipe outside 1.8×13 cm. Thermal wool was used as isolated material to cover the main container from outside and their thickness of thermal wool was 0.5 cm. The compressor model ZB-0.12/8 was used to deliver air into nozzle under 0.2 MPa (2 bar), 0.3 MPa (3 bar) and 0.4 MPa (4 bar). Pump model WW-9075-100 was water diaphragm pump, volts 24 VDC and open flow 1.42 LPM. Whey tank made from plastic and whey tank size was $11 \times 12 \times 15$ cm width, length and height. The whey tank carried by stand, it was 20×37 cm diameter and length respectively. The base of stand was 37×2 cm length and thickness. The two types of whey were used in current research the

solution prepared by editing the protein at different level 5%, 7% and 10%. The manometer pressure gauge used to measure the nozzle air pressure and liquid line. The first type was the whey powder. Electrical heater model Reco made from copper. It was used to heat inside tank. The PSGI wattmeter was used for measuring power required in watt. The HH309A is a small 4-input thermometer plus a powerful data logger. The unit can store up to 16,000 records per channel at programmed intervals. The unit comes with Windows-based software for the display and saving of data. The Centrifuge instrument used to separate the liquid from the powder in the collected samples.

Procedures

The experiment and fabricated spray concentrated unit or dryer unit was manufactured using the local materials to concentrate the whey under laboratory conditions in work shop and Lab of the Agricultural Engineering Department at Kafrelsheikh University. The fabricated spray dryer unit constricted and built as follows: Main tank, manometer for air and whey, pneumatic nozzle, electrical heater, valves, heat sensors PT100, compressor, PC, collector tank and whey pump as shown in Figure 1. Thermal wool was used to isolate of the main container from outside. Electrical heater model Reco 5/4 inch equipped with a thermostat was adjusted the temperature inside the main container at 80°C. The electric heater was adopted in the bottom of the main container. The PT 100 heat sensor was put and fixed in inner and outer main container. Three operating temperature were 66.5°C, 69.5°C and 72.5°C used at different operating pressure and different treatment conditions. The pneumatic nozzle was set up in the top of main container. The pneumatic nozzle was constructed with the whey pump in one side and connected with air compressor in other side of nozzle. The compressor model ZB-0.12/8 was adjusted to obtain different operating air pressure 0.2 MPa (2 bar), 0.3 MPa and 0.4 MPa for induction nozzle atomizer.

The valves of whey and air valve were used to obtain the different liquid pressure (whey) and air pressure. The diaphragm pump model WW-9075-100 was adjusted at operating pressure 0.1 MPa and two open valve setting full and half. The different types of whey were used in current research the solution prepared by editing the protein at different level 5%, 7% and 10%. In addition to the natural whey was collected from Dairy laboratory, Faculty of Agriculture, Kafrelsheikh University and treated under above treatment conditions. The electrical energy consumed was recorded and measured for heater, compressor and whey pump. Also, the sensors PT100 was connected with PC to measure the temperature in four points, one in outside and two point inside of top and bottom of the main container and fourth point in whey outlet collected. The samples were collected after every treatment

and put into the centrifuge instrument to separate the liquid from the powder at 5000 and 10000 rpm.

Purifying process steps

One liter of water was added to one liter of BD, the mixture of water and BD to obtain the solution that will be spraying into the fabricated concentrated unit.

Results and Discussion

The results attained from this study are discussed under the following points:

Power and energy consumed

The power requirement to concentrate the different whey percentage concentration was illustrated in Figure 2 and Table 1 at different operating pressure for pneumatic nozzle atomizer (Lechler 156.000.35.11). The total power to operate the spray concentrated unit or dryer unit, the compressor, the heater and the pump was 1.952 kW, 2.043 kW and 2.088 kW for operating air compressor pressure 0.2 MPa, 0.3 MPa and 0.4 MPa respectively. As well as, the energy consumed was 0.0325 kW. h, 0.0341 kW. h and 0.0348 kW. h for operating air compressor pressure 0.2 MPa, 0.3 MPa and 0.4 MPa respectively. On the other hand, the specific energy requirement to concentrate one litter of whey was 0.325 kW h l⁻¹, 0.272 kW.h l⁻¹ and 0.139 kW h l⁻¹ at operating air compressor pressure 0.2 MPa, 0.3 MPa and 0.4 MPa respectively. From the above result, the increasing of operating pressure for pneumatic nozzle atomizer of whey in spray dryer unit tends to reduce the energy consumption due to increasing the feeding amount

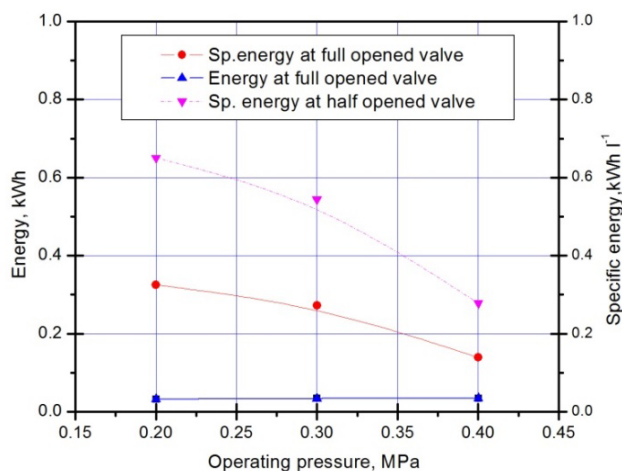


Fig. 2. The power requirement to concentrate the different whey at different operating air atomizer pressure

Table 1. The power requirement to concentrate the different whey percentage concentration at different operating air atomizer pressure, full and half opened valve of liquid (Whey)

Pressure, MPa	Power requirement				Energy consumed		Energy consumed, kW h l ⁻¹		
	Compr., W	Heater, W	Pump, W	Total power, W	Total power, kW	W. h	kW. h	Full opened valve	Half opened valve
0.2	986	960.0	6	1952	1.952	32.53	0.0325	0.325	0.650
0.3	1077	960.0	6	2043	2.043	34.05	0.0341	0.272	0.544
0.4	1122	960.0	6	2088	2.088	34.80	0.0348	0.139	0.278

of whey (flow rate) during the atomization of whey. Effect of Air pressure in induction nozzle on whey concentration The results revealed that increasing the air pressure to operate the pneumatic nozzle tends to increase the whey concentration produced from the spray concentrated unit or dryer at for different input concentration 5 %, 7%, 10% and chaise collected whey at full and half open valve of the liquid flow rate, 0.1 l min⁻¹, 0.125 l.min⁻¹ and 0.25 l min⁻¹. The maximum whey concentration produced from the spray concentrated unit or dryer at full open valve and input concentration 10% solution were 37.59 %, 39.07% and 39.35% at operating pressure 0.2 MPa, 0.3 MPa and 0.4 MPa respectively.

The whey concentration produced values from the spray concentrated unit or dryer at full open valve and input concentration 5% solution were 36.2%, 36.6 % and 37.5 % at operating pressure 0.2 MPa, 0.3 MPa and 0.4 MPa respectively. The whey concentration produced values from the spray concentrated unit or dryer at full open valve and input concentration 7% solution were 35.08 %, 36.58% and 38.17 % at operating

pressure 0.2 MPa, 0.3 MPa and 0.4 MPa respectively. The whey concentration produced values from the spray concentrated unit or dryer at full open valve and input concentration chaise whey collected were 34.64%, 34.78% and 35.51% at operating pressure 0.2 MPa, 0.3 MPa and 0.4 MPa respectively as shown in Figure 3. On the other hand, the maximum whey concentration produced from the spray concentrated unit or dryer at half open valve and input concentration 10% solution were 38.31%, 39.75% and 40.02% at operating pressure 0.2 MPa, 0.3 MPa and 0.4 MPa respectively.

The whey concentration produced values from the spray concentrated unit or dryer at half open valve and input concentration 5% solution were 39.19%, 38.29% and 39.24% at operating pressure 0.2 MPa, 0.3 MPa and 0.4 MPa respectively. The whey concentration produced values from the spray concentrated unit or dryer at half open valve and input concentration 7% solution were 36.79%, 37.02% and 35.61% at operating pressure 0.2 MPa, 0.3 MPa and 0.4 MPa respectively shown in Figure 4 effect of operating tempera-

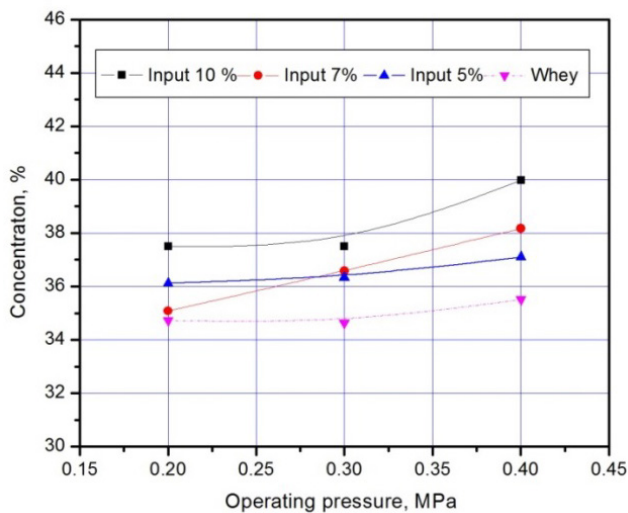
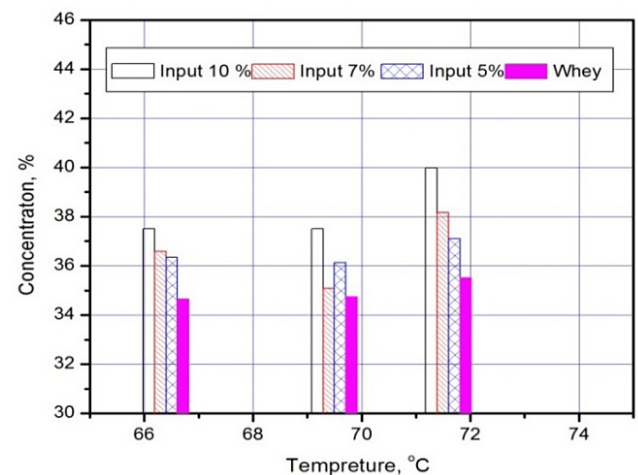
**Fig. 3. The effect of operating air induction nozzle pressure on the concentration percent of whey, produced from spray concentrated unit, or dryer unit at full open valve of liquid and different input concentration of whey****Fig. 4. The effect of operating air induction nozzle pressure on the concentration percent of whey, produced from spray concentrated unit, or dryer unit at half open valve of liquid and different input concentration of whey**

Table 2. The physical properties of concentrated whey at complete feeding open valve

Feeding concentration, %	Pressure, MPa	Density, gcm ⁻³	PH	Output Concentration, %
5%	0.2	1.025	6.45	36.2
	0.3	1.032	6.38	36.6
	0.4	1.012	6.36	37.5
7%	0.2	1.029	6.38	35.08
	0.3	1.012	6.31	36.58
	0.4	1.026	6.28	38.17
10%	0.2	1.030	6.46	37.59
	0.3	1.033	6.38	39.07
	0.4	1.060	6.37	39.35
Whey	0.2	0.908	6.23	34.64
	0.3	0.859	6.08	34.78
	0.4	0.812	6.17	35.51

Table 3. The physical properties of concentrated whey at half feeding open valve

Feeding concentration, %	Pressure, MPa	Density, gcm ⁻³	PH	Output Concentration, %
5%	0.2	1.012	6.44	39.19
	0.3	1.067	6.41	38.29
	0.4	1.006	6.37	39.24
7%	0.2	1.092	6.37	36.79
	0.3	1.061	6.29	37.02
	0.4	1.064	6.28	35.61
10%				38.31
	0.2	1.049	6.29	39.75
	0.3	0.986	6.14	40.02
	0.4	0.972	6.12	NR
Whey	NR	NR	NR	NR
	NR	NR	NR	39.19
	NR	NR	NR	38.29

ture on whey concentration. The results revealed that increasing the operating temperature of the fabricated spray concentrated unit or dryer tends to increase the whey concentration produced from the fabricated spray concentrated unit or dryer for different input concentration 5 %, 7%, 10% and chaise collected whey at full and half open valve of the liquid (flow rate, 0.1 l min⁻¹, 0.125 l min⁻¹ and 0.25 l min⁻¹). The maximum whey concentration produced from the spray concentrated unit or dryer at full open valve and input concentration 10% solution were 37.59 %, 39.07% and 39.35% at operating temperature of the spray concentrated unit or dryer unit respectively.

The whey concentration produced values from the spray concentrated unit or dryer unit or dryer at full open valve and input concentration 5% solution were 36.2%, 36.6% and 37.5% at operating temperature of the spray concentrated unit or dryer 66.5°C, 69.5°C and 72.5°C respectively. The whey concentration produced values from the spray concentrated unit or dryer at full open valve and input concentration chaise whey collected were 34.64%, 34.78% and 35.51% at operating temperature of the fabricated spray concentrated unit or dryer respectively as shown in Figure 5. On the other hand, the maximum whey concentration produced from the spray concentrated unit or dryer at half open valve and input concentration 10% solution were 38.31%, 39.75% and 40.02% at operating temperature of the spray concentrated unit or dryer 66.5°C, 69.5°C and 72.5°C respectively.

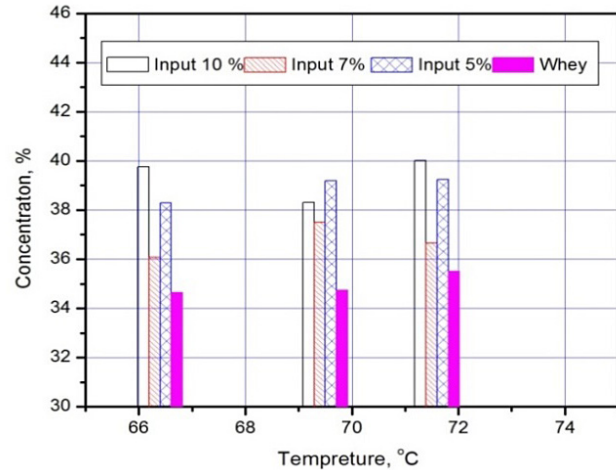


Fig. 5. The effect of operating temperature on the concentration percent of whey produced from spray concentrated unit, or dryer unit at full open valve of liquid and different input concentration of whey

The whey concentration produced values from the spray concentrated unit or dryer unit at half open valve and input concentration 5% solution were 39.19%, 38.29% and 39.24% at operating temperature of the spray concentrated unit or dryer respectively. The whey concentration produced values from the spray concentrated unit or dryer unit at half open valve and input concentration 7% solution were 36.79%, 37.02% and 35.61% at operating temperature of the spray concentrated unit or dryer 66.5°C, 69.5°C and 72.5°C respectively shown in Figure 6.

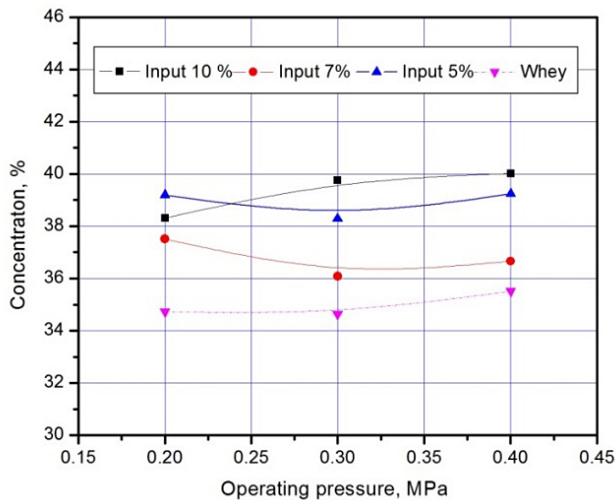


Fig. 6. The effect of operating temperature on the concentration percent of whey produced from spray concentrated unit, or dryer unit at half open valve of liquid and different input concentration of whey

Conclusion

The present study concluded that the ability to concentrate the whey by using the manufactured spray concentrated unit or dryer. The increasing of operating pressure for pneumatic nozzle atomizer of whey in fabricated spray dryer unit tends to reduce the energy consumption due to increasing the feeding amount of whey (flow rate) during the atomization of whey. On the other hand, the maximum whey concentration produced from the spray concentrated unit or dryer was found at half open valve compared with the full open valve of the whey pump inlet to pneumatic nozzle atomizer. This result may be due to the low amount of whey liquid into the fabricated spray concentrated unit or dryer during the atomization process. Also the pneumatic nozzle atomizer could be able to produce the fine droplet size in half open valve setting under these operating conditions.

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