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Design of an Automated System for Liquid Foods Production

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Abstract: *The following pages describe in depth the design of an automated production system for liquid foods with capacity of 750 liters per hour. The system is designed to meet various high quality standards, process different volumes of fluid and give maximum output with minimum waste and cost.*

Keywords: *Production automation, liquid food processing, food engineering.*

1. Introduction

Production automation has become more and more necessary among the factories around the world. Unlike many other industries, food manufacturing is not highly sensitive to economic conditions; therefore the rate of return of an investment in an automated food production system is much higher, compared to others. On the other hand, food production requires a lot of responsibility due to the high risk of food contamination and microbial growth which could lead to fatal consequences. The work in food manufacturing plants involves repetitive, physically demanding work thus making the employees highly susceptible to repetitive strain injuries [1, 2]. Thus, not only is food production automation cost effective, but it also eliminates repetitive jobs, ensures consistency and high quality of the products, decreases the risk of contamination, and increases profitability by decreasing waste and increasing productivity.

2. Production processes in an automated liquid foods production system

Some of the most common production processes in liquid foods manufacturing involve various processes such as follow.

Mixing and preheating. Liquid food production always starts with mixing the raw ingredients in order to obtain the initial mixture.

Preheating. Depending on the product and recipe, in most cases dry ingredients have to be added to the initial mixture in order to obtain the final mixture. For that reason the initial mixture has to be preheated to about 30°C and then dry ingredients added, in order for them to dissipate in a proper way.

Pasteurizing/Sterilizing. Liquid food manufacturing always hides huge amount of risk of bacteria growth. In order to avoid that, techniques such as pasteurization and sterilization are used. Pasteurization means heating the product to a specific temperature for a definite amount of time, and then cooling it down immediately. The process is intended to reduce the number of viable pathogens so they are unlikely to cause disease. On the other hand, sterilization is aimed to kill all micro-organisms in food and for this reason it is not widely used within the variety of foods around us [1].

Cooling. Low temperatures prevent food poisoning bacteria, which may be present in the food, from multiplying to dangerous levels. Pasteurization does not eliminate a hundred percent of the bacteria; some of them are still present in the food after the process and could multiply exponentially if the food is left long enough in the Temperature Danger Zone (5-60°C) [3]. Due to these conditions, forced cooling is a crucial process in liquid food manufacturing and has to be quick in order to avoid any unwelcome results.

Depositing. Once the final mixture has reached the necessary temperature, it must be deposited into containers as fast as possible in order to avoid second temperature raise, which will damage the texture. In most cases the cheapest and most effective solution is the use of pneumatic pistons mounted on a C-Frame above a conveyor belt.

Freezing. Rapid freezing is required for most products to ensure minimal damage to the product texture and minimize bacteria growth [1].

Packaging. Packaging is the last step of all processes. It must be implemented in such a way that it would prevent the product from contamination, is presentable and cost effective. Automated Production of Crème Brule and the Equipment Required.

3. Processes in crème brule production automation and food processing equipment required

Crème Brule is an exquisite dessert with very high quality. It is a high viscous fluid with very fine texture, which is sensitive to temperature changes. Due to its recipe, the crème is also perfect environment for bacteria multiplication, which requires pasteurization and sanitary production system design. In order to manufacture Crème Brule in an industrial facility the following steps have to be followed.

3.1. Mixing, preheating, and cooking

The initial step into making Crème Brule is to mix the liquid raw ingredients, warm up the mixture to 30°C; add the sifted dry ingredients and then heat to 70°C, while still mixing. In practice the three processes can be executed with only one piece of equipment. Proper solution to this is a steam jacketed cooking kettle with agitator for mixing purposes. This type of kettles have hollow jacket around their surface, through which hot steam circulates under pressure in order to increase the temperature of a product inside the kettle. Two kettles of that type with volumes of 1100 l and 900 l have been chosen to increase efficiency and production rates. Since this is a direct food contact equipment all surfaces are stainless steel grade 316 and are smooth and crevice free to avoid corrosion. The horizontal scraped surface agitator ensures even distribution of heat throughout the product, reduces burn-on, and provides better mixing, particularly with products containing particulates, such as Crème Brule. In order to avoid improper heat treatment the crème level in the kettle during production should not exceed the steam jacket top line. Because of this fact, the maximum amount of processed crème in each kettle is respectively: 500 l and 450 l for Kettle 1 and Kettle 2.

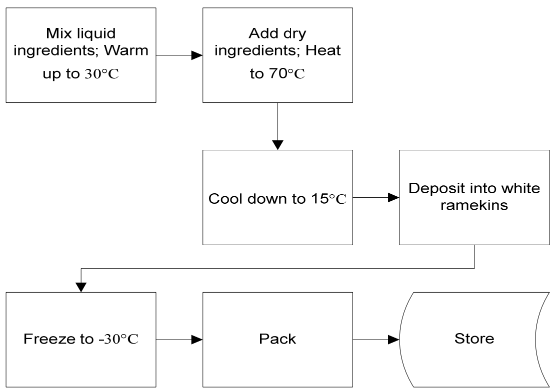

Fig. 1. Scheme of Crème Brule production system

Fig. 2. Steam jacketed cooking Kettle and steam boiler 50 hp

3.2. Cooling

Once the Crème has reached 70°C, it has to be cooled down to 10-15°C within a very short time period in order to avoid bacteria growth. The temperature zone 5-60°C is considered Temperature Danger Zone where bacteria can grow to unsafe levels. This process requires a heat exchanger with proper length to be used to cool down the crème to the desired temperature. Due to the high viscosity of the final crème, the most efficient heat exchanger would be a tubular heat exchanger with volume of 900 l. In order to ensure high heat exchange rate, the surface should be shaped into turbulence-inducing (corrugated), alternating parallel grooves and ridges to increase heat transfer efficiency. Inducing turbulent flow results in less total surface area required to achieve the desired thermal results. Turbulent flow promotes thorough mixing of the product and even thermal disbursement without compromising product integrity. Product moves upward from one tube to the other through the jumpers made from sanitary elbows. Media flows downward to optimize the heat transfer capability by using the counter current flow. Fluid transfer is accomplished by means of a positive displacement pump and pipes connecting the kettles and the heat exchanger [4].

Fig. 3. Corrugated double tube Heat Exchanger (input temperature 70°C; output temperature 10°C)

The next step after cooling is depositing the crème into containers. Since the hopper volume of a regular depositing line is much less than the tubular heat exchanger volume, a buffer cold storage piece of equipment has to be implemented between them, where the crème will keep its low temperature until being processed through the depositors. The second raise of the crème temperature will lead to damage of the texture of the fluid, which will decrease the product quality.

For this operation a standard PZ-CB processor with volume of 1100 l has been chosen. It features a cone bottom, pitched to a center outlet and a process agitator assembly for mixing purposes, scraper with removable molded nylon blades which continuously wipe the bottom and sidewalls to blend the product, increase the heat transfer efficiency and aid in unloading. The stainless steel heat transfer jacket, covering the sidewalls and bottom, is designed for operating pressures up to 21.4 kPa at 160°C as a standard.

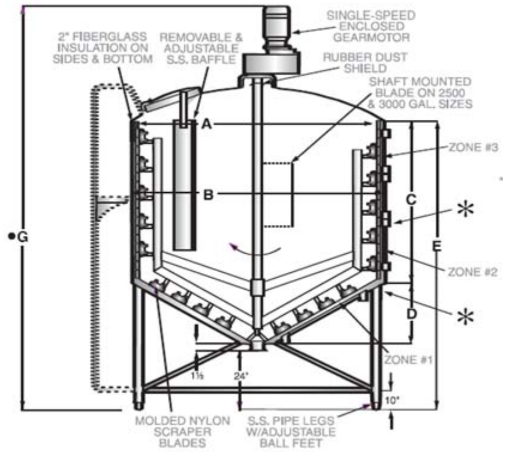

Fig. 4. PZ-CB Processor

The cold water supply for the double tube heat exchanger and chilling tank is ensured by air agitated ice builder system located outside of the facility, which is by far the most efficient and economic method used for this purpose. By storing the refrigerating effect, in the form of ice, this unit provides the single most efficient means of accommodating every possible process load that relies on recirculated cold water as its heat exchange medium. The ice builder method has a capacity of 9800 l of 0.5°C water which is distributed to the heat exchanger and the chilling tank by means of a water pump [5].

Fig. 5. Air agitated ice builder

3.3. Depositing

The cold Crème Brule is transferred from the chilling tank to a depositing line by means of a 3 HP positive displacement pump with VFD (Variable Frequency Drive) and pipes.

The depositing system consists of a 4 m slide bed conveyor and one Multi-Depositor. The Multi Depositor is a standard M8 Multi Depositor fitted with a Diving Bridge on a C-frame stand. It is supplied with positive cut-off nozzles and adjustable center distance between nozzles. Prior to depositing, sheet pans with 40

Crème Brule ramekins are placed manually on the conveyor belt of the depositor. A photo eye is mounted on the belt, which detects each row of containers and activates a controller, which causes the belt to stop for the deposit [6].

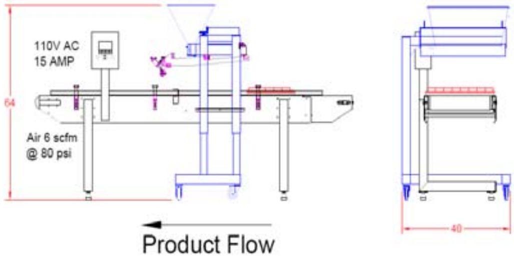

Fig. 6. Depositing system layout and product flow

3.4. Freezing

Due to the high quality standard of Crème Brule, immersion has to be used as a form of direct-contact freezing, which means a freezer has to be chosen with individual quick freezing (IQF) capabilities. With such freezers, the product is carried into a bath of carbon dioxide and is conveyed through the liquid while the refrigerant changes from liquid to vapor and absorbs heat from the product. Consequently, a spiral freezer is placed right after the depositing line, where the product travels 45 min along a spiral conveyor belt inside the freezer to obtain a final temperature of –30°C. Considering the speed of the belt, the freezer's capacity is 50 units per minute

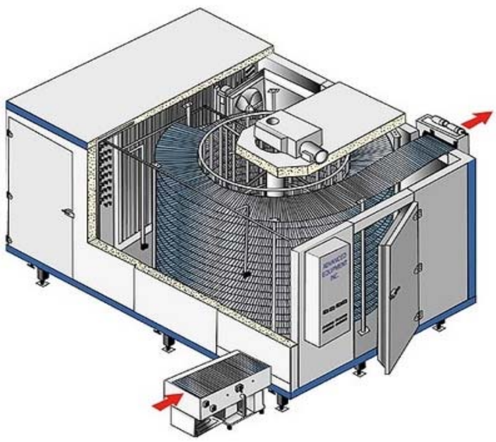

Fig. 7. Spiral freezer

3.5. Packing

As soon as the frozen crème exits the spiral freezer, it must be packed quickly in order to avoid thaw out of the product. Initially, the Crème Brule ramekins have to be shrink wrapped in order to be protected from contamination before they reach the end consumer.

A Hy-Speed HS-1 Automatic Shrink Wrapper is placed after the spiral freezer with linear speed of 40 m per 1 minute and operating at compressed air at 12 kPa. By means of a series of conveyor belts the frozen product is brought to the shrink wrapper, where a plastic film is applied to the Crème.

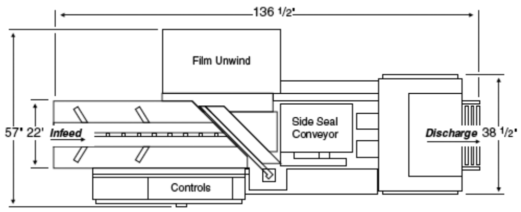

Fig. 8. Hy-Speed HS-1 Automatic Shrink Wrapper

Fig. 9. HEAT tunnel

The already scanned for unwanted particles Crème Brule is ready for final packaging. Sets of four Crème Brule ramekins have to be placed in carton boxes before they reach the final consumer. The ideal machine for this operation is the HC-3200 high quality automatic horizontal servo indexing cartoner, which erects, closes, glues cartons and inserts the product into the cartons. The machine has a capacity of 80 cartons per minute and a laser engraving the expiration date, mounted on its exit belt [8].

Fig. 10. Loma IQ3 metal detector

Fig. 11. Automatic horizontal servo indexing cartoner Model: HC-3200

The final part of the packaging process is placing 20 cartons of Crème Brule in a master case and palletize. The master cases are processed manually, due to economical reasons related with the incredibly high prices of robots and low rates of return. The master cases are run through a tape machine to ensure tight seal, then palletized and distributed within the customer network.

3.6. Sanitation

A Sani-Matic Clean-In-Place/Clean-Out of-Place (CIP/COP) system is installed for automatic sanitation of the food processing equipment such as kettles, tanks and heat exchanger [9]. The CIP unit uses water from the City Water Supply, adds detergent, and pumps it through a Steam Trap to gain heat. The hot water then is pumped to the food processing equipment in order to clean and sanitize. Finally, the water returns back to the CIP where it is sent to a drain.

4. Cost analysis

4.1. Labor costs

Direct labor cost: include the wages of all labor that can be traced specifically and exclusively to the manufactured goods in an economically feasible way. Five people at the wage of $10 per hour are involved in the designed system production. Consequently, $50 is spent per man-hour.

The system capacity is 50 units per minute, since the bottleneck is the spiral freezer. Therefore the direct labor cost per unit is: 50/3000 = $0.017 per unit.

Indirect labor cost: The cost for employees or workers, who do not directly produce goods or services, but who make the production possible or more efficient. Indirect labor costs are not readily identifiable with a specific task or work order. They are termed indirect costs and are charged to overhead accounts. The indirect labor cost in this case is 10% of the direct labor cost. Therefore, the indirect labor is $5 per man hour.

Total labor cost: direct + indirect costs are $55 per man hour or 55/3000 gives $0.0183 per unit.

4.2. Material costs

The material costs include the costs for raw materials and packaging. These costs may vary within different vendors and different times throughout the year. In this case, it is know from Purchasing department that the total material cost per Crème Brule is $2.50.

4.3. Overhead costs

The overhead percentage in that case is 30% of the total labor cost. Therefore the overhead cost = 0.3×55 = \$16.50 per hour or \$0.0055 per unit produced.

Total cost = Total labor cost + Material Cost + Overheads Percentage Cost = 0.018 + 2.50 + 0.0055 = \$2.52 per unit.

During production runs for this product, about 4% of the crème becomes scrap due to various reasons.

Therefore the average final cost for the product it 2.52 + 0.04×2.52 = \$2.62 per unit.

Fig. 12. A Clean-In-Place (CIP) system from Sani-Matic

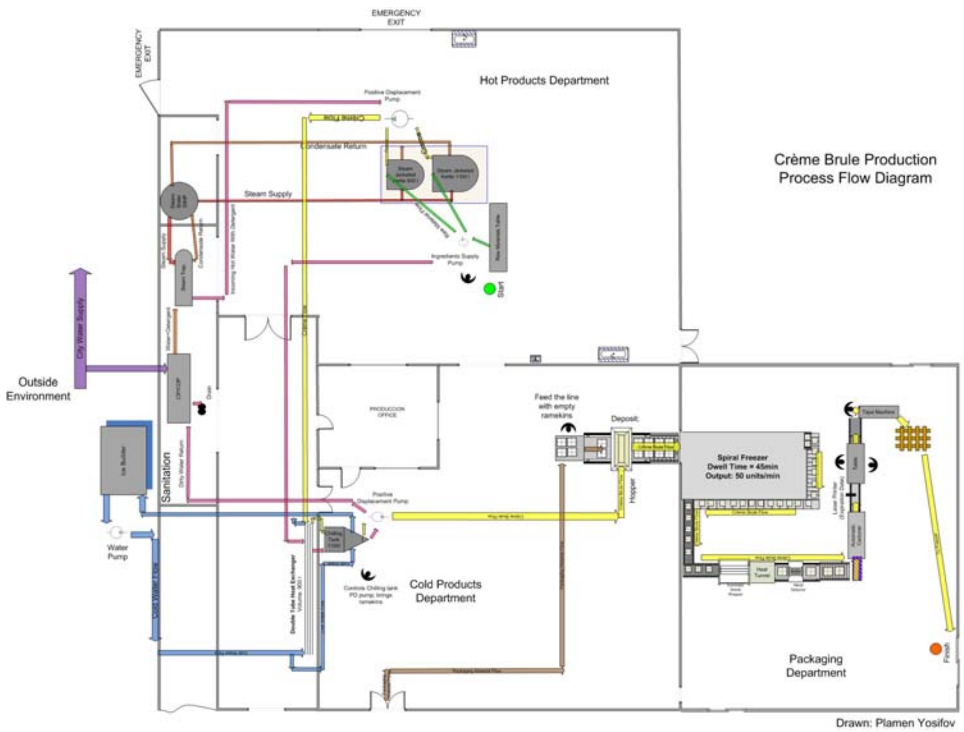

Fig. 13

5. Conclusion

The designed system not only is suitable for Crème Brule production, but also for production of all kinds of liquid foods such as crèmes, mousses, sauces, jelly fillings, etc. It is very flexible in terms of quality and production requirements, it is cost effective with regards to labor and time savings, and has a total capacity of 750 l/h. The sanitary design provides high level of food safety during the production processes.

References

1. S i n g h, R. P., D. R. H e l d m a n. Introduction to Food Engineering. Fourth Edition. USA, 2009.
2. S m i t h, P. G. Introduction to Food Process Engineerin. London, 2010.
3. **www.foodsafety.asn.au**
4. **www.thermaline.com/tubedetails.htm**
5. **www.chester-jensen.com/p_ice_builder.html**
6. **www.unifiller.com/bakery-machines/multi-piston-depositor**
7. **www.loma.com/docs**
8. **www.consolidatedtechnologies.ca**
9. **www.sanimatic.com**

Разработка автоматизированной системы для производства жидких пищевых продуктов

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(Р е з ю м е)

В статье описывается в деталях автоматизированная система для производства жидких пищевых продуктов капацитетом 750 l/h. Система разработана так, чтобы удовлетворить высоким стандартам, производить разные количества жидкости и дать максимальную производительность при минималном расходе и по минимальной цене.