Design and Performance Test of Steamer Cabinet for Fish Jelly Products

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Abstract. There is need for a detailed assessment of raw material quality during product development. This study focuses on the performance test of steamer cabinet for fish jelly production. The machine was designed in rectangular shape with 46 cm length, 45 cm width, and 110 cm height, comprising steam generator, burner chamber, wall, tray, and channel. In addition, eight baking sheets were vertically incorporated. Performance test was performed to determine temperature distribution of fish jelly/nugget and individual shelves. This process was conducted with/without load conditions, where parameters, including room cabinet and fish nugget temperatures, as well as fuel usage efficiency, were observed. Furthermore, temperature measurements were also recorded at the top (T1), middle (T2 and T3) and bottom (T4) of the sample device. The results showed the room temperature of each tray was extended to 100°C under 40 minutes. However, no significant heat change was reported, indicating the steam from the generator was evenly distributed. Furthermore, fish nugget temperature was obtained at 80°C in 40 minutes, where at the top (T1), middle (T2 and T3) and bottom of the steamer cabinet, relatively similar occurrences were observed. The resulting vapour was steadily spread across the steam channel to individual shelves. Therefore, the fuel usage efficiency of the steamer cabinet was estimated at 67 %.

1. Introduction
In Indonesia, several opportunities are fast becoming available for fish jelly products. This type of processed food is very common among the populace, due to the easy-to-serve advantage. Fish nugget are a diversification of fish jelly, and are produced from a mixture of surimi, flour, and other seasonings [1], using the steps of dough mixing, moulding, and steaming [2]. Prior to the nugget production, fish fillets, additives, and other constitutes were weighed, depending on the product formulation [3]. Subsequently, the nuggets were sliced into rectangular forms and well coated, before frying. Steaming refers to the heating process aimed at deactivating the active enzymes responsible for colour change, flavour, and nutritional value, using a temperature between 82-100°C. This stage tends to reduce available nutrients, but not as high as boiling. However, on occasional basis, the product temperatures at the edge are relatively higher, compared to the middle placement [4], and after steaming, the resulting materials are mainly frozen or preserved at low temperatures [5].

Domestic fish nugget production is manually achieved with simple equipment, including meat grinder, mixer, and steamer. In Indonesia, the steamer utilized in the fish jelly dough generally involves a pan (60 cm diameter), comprised of water, before further heating with LPG (Liquefied Petroleum Gas). This steamer also consists of two stacks, with the ability to load 6 trays, although, nugget heat
process lasts for approximately 45 minutes. Several obstacles were encountered in this conventional method, including: excessive time usage, minimal equipment capacity, and extreme water vapour discharge. Readily available commercial steamers generally exhibit large capacity, require large fuel consumption, and are relatively expensive. Interestingly, a common steamer cabinet is needed to resolve these setbacks. This research, therefore, was aimed at designing a simple steamer cabinet with capacity up to 40 kg/hr, affordable, low fuel consumption, and also suitable for domestic fish jelly production.

2. Materials and Methods

2.1 Materials
The materials employed in constructing steamer cabinet were stainless steel plates (ss 304) with 1 and 1.2 mm thickness, stainless steel hollow (ss 304) with 2 cm width, glass with 5 mm thickness, and LPG-gas stoves. In terms of equipment, tools for bending KW 1500901, cutting MT 90, and drilling Makita 6412, as well as other workshop kits were applied. However, performance testing utilized thermometer TM-946 and stop watch.

2.2 Methods
The design criteria for steamer cabinet were to produce nuggets according to the National Standard of Indonesia (SNI 7758: 2013), using food grade materials, steaming temperatures up to 80°C, water vapor, and LPG fuel generator, with capacity up to 40 kg/hour. Table 1 shows the steamer cabinet functional design.

| Function                        | Part              |
|---------------------------------|-------------------|
| Fuel                            | LPG               |
| Heating fish jelly product      | Water vapour      |
| Setting the steamer’s chamber-  | Thermostat        |
| temperature                      |                   |
| Producing water vapour          | Steam generator   |
| Removing combustion gas         | Exhaust gas channel|
| Circulating water vapour        | Vapour channel    |
| Putting fish jelly              | Tray              |
| Heating water                   | Burner chamber    |

2.3 Manufacturing
The steamer cabinet, consisting of eight shelves, was designed in rectangular shape with 46 cm length, 45 cm width, and 110 cm height, with the capacity measured up to 40 kg/hr. Trays produced from SS (304) with dimensions of 0.5 mm thick, 40 cm width, 40 cm length, and 2 cm thickness were introduced into these compartments. In addition, the door involved glass with 5 mm thickness for easier visibility, and the boiler was produced with SS (304) 0.5 mm thickness, suitable to boil water. Also, the walls composed of 1.2 mm stainless steel plate, with a framework of 2x2 mm hollow stainless steel. Subsequently, the boiler was positioned at the bottom, prior to heating, and the water vapor was observed to flow upward for uniform heat distribution. Moreover, the exhaust gas channel was constructed, using stainless pipe of 5 cm diameter of 5 cm, for easier vapor discharge. Figure 1 describes the entire process of the steamer design and the fluid flow mechanism.
2.4 Performance Test

Performance tests were conducted, in an effort to determine the temperature distribution of individual tray on steamer cabinet without load conditions. The fish nugget temperature and fuel usage efficiency were also evaluated. These assessments were performed in duplicates by measuring the temperatures at the bottom, middle, and top, in every 5 minutes up to equilibrium. Furthermore, the fuel usage efficiency was obtained with the equation:

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\text{Efficiency of fuel usage} (\%) = \frac{\text{theoretical fuel usage}}{\text{actual fuel usage}}
\]  

(1)

2.5 Data Analysis

Statistical data processing was engaged, in order to determine the temperature difference on each cabinet tray, using ANOVA (Analysis of Variance) with SPSS software (95% confidence interval).

3. Result and Discussion

Figure 2 displays the steamer cabinet design, as well as evaluates the temperature measurements at top (T1), middle (T2 and T3), and bottom (T4). Meanwhile, Figure 3 represents the room temperature results of individual trays to a maximum of 100 °C, under 40 minutes. Statistical analysis confirmed no significant temperature change was obtained (p>0.05), indicating a uniform steam distribution. Water vapor tends to flow properly from boiler to entire cabinet, through the steam channel. Condensation ducts were designed, using the total wall surface to enable consistent flow. The results of fish nugget temperature was approximately 80°C, with similar conditions at the top (T1), middle (T2 and T3) and bottom (Figure 4). Subsequently, fish nugget emulsion was firmly packed into rectangular aluminum moulds and steam cooked in a specially designed vessel for 40 minutes, with no pressure applied [7]. Heat transfer from steam to the nuggets was achieved by convection, and was also evenly distributed across the entire component.
Figure 2. The steamer cabinet and temperature measurements point

Figure 3. Room cabinet temperature (without load)

Figure 4. Fish nugget temperature
Based on the calculation (Table 2), steaming process without load conditions, indicated fuel consumption of about 0.26 kg in 40 minutes, but showed real estimate of 0.39 kg, using LPG. Fuel usage efficiency was obtained at a relatively low value of 67 %, with equation (1). This circumstance confirmed the occurrence of heat release through the steamer cabinet walls. Moreover, the heat transfer was due to temperature variation between steamer chamber and the environment, by conduction and convection processes. Convection occurred between the solid media and the surrounding fluid, extending to the environment. The rate of heat transfer by conduction is directly proportional to the heat conductivity value, and the cross-sectional area, but inversely proportional to material thickness [8].

This transfer phenomenon showed a reduction tendency by the addition of insulators to the cabinet’s wall surface. Materials employed as insulators include silicon rubbers [9], although, other non-conductors with low thermal conductivity, termed polymers, ceramics, and polymers composites, are also commonly applied [10].

Table 2. Fuel usage of steamer cabinet

| Time (minutes) | Fuel usage (Kg) | Water usage (Kg) |
|---------------|-----------------|-----------------|
| 55            | 0.5             | 3.65            |
| 40            | 0.39            | 2.04            |

4. Conclusion
Based on results and discussions, steamer cabinet are known to uniformly distribute steam from the generator to individual trays, with temperature extending to 100°C under 40 minutes. Performance tests obtained a maximum nugget temperature of 80°C, in similar interval. In addition, the fuel usage efficiency was estimated at 67%. Therefore, statistical analysis observed no significant temperature change.

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References
[1] Ojagh S. M., Shabanpour B. and Jamshidi A. 2013. “The effect of different pre-fried temperatures on physical and chemical characteristics of silver carp fish (hypophthalmichthys molitrix) nuggets” *Journal of Fish and Marine Sciences*, vol. 5, no. 4, pp. 414-420.
[2] Gozali T., Sutrisno A.D., and Ernida D. 2001 “Pengaruh waktu pengukusan dan perbandingan jamur tiram terhadap karakteristik nugget jamur tiram putih (plyeroyusflorida)” *Prosiding Seminar Nasional Teknologi Pangan Semarang* [in Indonesian]
[3] Silva A., Zitkoski J., Mazutti M.A., Mossi A., Oliveira J.V., Oliveira D., Cichoski A.J., and Treichel H. 2011 “Evaluation of process parameters in the industrial scale production of fish nuggets”, *Ciência e Tecnologia de Alimentos*, vol. 31, no. 2, p. 406-411.
[4] Romdhijati L. 2010 “Olahan Dari Kentang”, *Kanisus*, Yogyakarta [in Indonesian]
[5] Tan S.M. 1994 “Processing of marinated fish and battered a nd breaded fish burger and nugget”, *ASEAN-Canada Fisheries Post Harvested Technology Project Phase II*, FAO, Rome, 82.
[6] Amalia U., Darmanto Y.S., Sumardianto, Rianingsih L. 2016 “Chemical Characteristics of Fish Nugget with Mangrove Fruit Flour Substitution”, *Aquatic Procedia*, 7, pp. 265 – 270.
[7] Rahul M., Khandagale, R.C. Keshri, Kumar P., Singh P.K. 2013. “Microbial quality of pork nuggets incorporated with fish flesh under refrigeration”, *Journal of Animal Research*, 3, 1, pp. 37-41.
[8] Khamkar N. 2017. “Heat Sink Design For Optimal Performance Of Compact Electronic Appliances - a Review”, *Journal for Advanced Research in Applied Sciences*, 4, pp. 13-21.
[9] Ansorge S., Schmuck F. and Papailiou K.O. 2012. “Improved Silicone Rubbers for the Use as Housing Material in Composite Insulators”, *IEEE Transactions on Dielectrics and Electrical Insulation*, 19, 1, pp. 209-217.
[10] Chen H., Ginzburg V.V., Yang J., Yang Y., Liu W., Huang Y., Du L., and Chen B. 2016. “Thermal conductivity of polymer-based composites”, Fundamentals and applications Progress in Polymer Science, 59, p.41–85