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Design and Functional Characteristic of Special Steamer for Natural Tofu Production

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Abstract: This paper examines the basic concepts of steaming phenomenon of soybean slurry in automatic steamer in the production process of natural tofu. Researchers are trying to develop natural tofu processing machine effectively with minimum cost. This study discusses teoritically the stages of the steamer, ranging from heat transfer, the temperature increasing of the water, the evaporation in the evaporator, the flow of steam to the steamer, heat transfer from steam to soybean slurry inside the steamer, increase of temperature on soybean slurry until reach its boiling point inside the steamer, until the stage of filtering. Natural tofu processing machine has been successfully created and tested empirically with its functional characteristics of some component has been proved could build an automatic mechanic system.

Key words: Natural tofu · Tofu processing · Steamer · Soybean

INTRODUCTION

Small and medium industrial technology systems for the agricultural industry must always be increase, along with increasing of competition in the global era [1]. Small industrial system resilience is determined by the control system in which production involves customer needs. Therefore, the policy of small and medium business technology requires integration between the aesthetic, intellectual, emotional [2]. For a more focused, should consider the efficiency of the process through technology [3]. Long time production process results low efficiency and increased production costs. Generally, such conditions encourage the state of small business to a critical threshold in order to face of global competition. In particular, the phenomenon of resilience of small and medium industry is also faced by the natural tofu industry that had been managed conventionally.

Natural tofu is made of pure soybean using whey coagulant, while the non-natural tofu using additional material, which means it does not use whey coagulant, but use additional materials as coagulant as well as a thickening agent. Researchers have conducted a study in the form of research and technology exploration of tofu production system in terms of the five target areas, such as research and development of process technology, engineering machinery, the efficiency of production systems, steamer technology, automations phenomenon.

Research about process technology of processing non-natural tofu at tofu producing countries, especially China, Korea and Japan have done related to the effect of temperature on the elasticity of tofu [4]. Thermal soy tofu as a condition for the formation of tofu texture will determine the quality of tofu gel [5]. The temperature of the water heater in tofu manufacturing process determines the percentage content of nutrition on nitrogen, protein, oil, hydration, bulk density, fractures, texturs, elasticity, color [6]. The use of coagulant type determines the yield elasticity of tofu products obtained. The use of calcium sulfate (CS) obtained a higher yield out of the use of GDL (Glucono delta lactone) acid, acidity, whey [7].

The research about machinery technology development of non-natural tofu processing so far has been done with various types of automatic machines supporting continuous production system, which uses automation systems, hydraulic, pneumatic, mechanical and electrical. In the present, development of semi-automatic processing machines out in the construction of small-scale automated processing of tofu, conducted with nigari coagulation process. Mechanical movement is done by the engine components that are controlled by electrical automation [8, 9, 10].

Overview from other aspects is in the tofu processing by using the coagulant whey with the raw material of soybean called natural tofu. It turns out tools and processing machines used are still not affordable by many

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current and mechanization engineering requires innovation, natural tofu production systems still use conventional equipment, with low efficiency of production systems [11, 12, 13]. The main causes of these conditions is characteristics of the gel obtained from whey coagulation process coagulant is crisp, sensitive to breakage due to mechanical movement [14, 15]. Based on these facts, in order to increase the efficiency of natural tofu production systems, presents a processing technology is very important.

Aim of the Research: In this paper, create continuous steamer and the steam heating characteristic that change conventional tofu production to continuous natural tofu production. Special steamer designed automatically on natural tofu production with continuous cycle. In this design, heater unit be important component on tofu production process. Continuous cycle in steamer can change burner system from carburator due to batch system become continuous oxidation burner system with better efficiency. Testing is done on a machine that has been created by a mathematical model.

MATERIALS AND METHODS

Construction Design of Automatic Steamer: Conventional tofu production system at this time is affordable to maintain the quality of the product until meet customer requirements. So, the invented machine must be maintains the quality of the product. Heating technique is usually performed by boiling without stirring at temperature of 80°C slurry after filtering. But, splashing to prevent boiled over and following by continuous heating were done frequently. Final temperature could reach 105°C, appropriate to characteristic needs of natural tofu production.

Natural tofu processing consists of sorting soybeans variety until obtaining the tofu which is ready to be marketed. Soybean slurry heating could be done by two methods, boiling method and steaming method. Each of them has strength and weakness appropriate with the industry capacity. Heat transfer in steamer explained in Fig. 1 [14].

1st Stage: In this process, chemical energy of fuel change to heat energy through burning process inside the fireplace. Heat spray out at one point on fire-resistant stone as heat storage place until it reach work temperature to get burning quality with oxidation fire that would be radiated to the surface of evaporator bottom side.

2nd Stage: Radiation and convention process inside the fireplace. In this process, heat radiated from heat source at evaporator bottom side.

3rd Stage: Conduction at evaporator's bottom side thickness. In this process the heat flow from downside of evaporator bottom side to upside of evaporator through evaporator conduction material thickness.

4th Stage: Convection from evaporator bottomside to water. In this process, heat transfers through convection between the inside of evaporator to fluids that always moving due to temperature effect to be [15].

There are two types of heating after 4th stage, these are boiling system and steaming system. On boiling system after 4th stage go directly to 9th stage. Convenction heat from evaporator bottomside use to increase the slurry's temperature. While on steaming system, after 4th stage have to go through each stage, 5th, 6th, 7th and 8th stage until 9th stage. In this steaming stage, slurry were heated by steam from evaporator, so convention heat from evaporator bottomside never contact directly with soybean slurry. The heat received by boiled water from convention process to inside of evaporator bottomside use to increase the water temperature until reach its boiling point inside the evaporator. This heat called temperature increasing heat capacity become:

$$Q_c = MC(T_e - T_a) \quad (1)$$

7th Stage: Steam flow from evaporator to steamer. After obtain steam inside the evaporator, the steam flow to steamer by pipes. In this process, it assumed that there is no heat loss. The amount of heat brought by steam is equal to the amount of heat produced by evaporator as:

$$Q_e = Q_c + Q_L = Q_{ve} \quad (2)$$

Soybean slurry heating process by steam inside the steamer characterized by air buble that going up to slurry's surface as the signal of reaching its boiling point. It causes the pressure increase and piston position to the actuator as automatic system signal. The heat that brought from evaporator (Q_e) is used to increase slurry's temperature inside of steamer (Q_{cs}). Just a little amount (the value could be ignored) use to vaporizing (Q_{ls}). Heat transfer from Q_e to Q_{cs} and Q_{ls} happen through Q_v convection process. Before it, the steam changes to condensed vapor, Q_{cv}. It all happened inside of steamer.

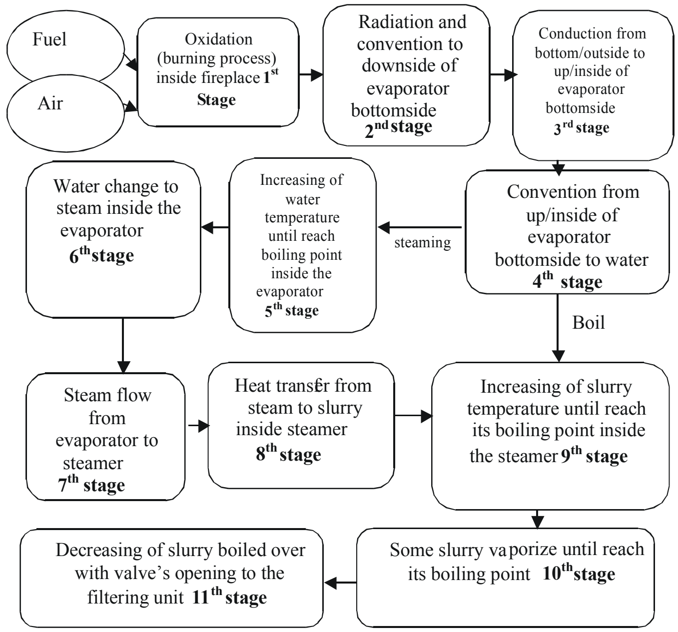

Fig. 1: Heat transfer scheme on tofu processing machine

Along with heat transfer by steam, slurry reaches its boiling point and boils over, as the signal strength automatically. The heat received is used to increasing slurry's temperature.

$$Q_e \geq Q_{cv} = Q_{cs} + Q_{ls} \quad (3)$$

Latent heat used to change water into steam in boiling process become:

$$Q_L = M_{steam}\ L_u \quad (4)$$

The amount of slurry steaming calor is very low, it happened at over boiling moment. So that, $Q_{ls} = 0$. And $Q_e = Q_{cs}$, it means steam calor which is given from evaporator equal to slurry temperature rising calor. Steam calor which is given from evaporator consist of 2 types, water temperature increasing calor (Q_c) and steaming calor (Q_L).

$$Q_e = Q_c + Q_L \quad (5)$$

$$= M_{water}\ C\ \Delta\ T_a + M_{water}$$
$$= M_{water}\ (C\ \Delta\ T_a + L)$$

$$\frac{Q_e}{t} = \frac{steamer\ mass\ from boiler}{time}(C\Delta T_a + L)$$
$$\frac{Q_e}{t} = k_e(C\Delta T_a + L) \quad (6)$$

While, soybean slurry's temperature increasing calory inside of steamer, the equation become:

$$Q_{cs} = M_s C_s\ (T_2 - T_1) \quad (7)$$

Slurry's temperature increasing calor with time unit:

$$\frac{Q_{cs}}{t} = \frac{M_s\, C_s (T_2 - T_1)}{t} \quad (8)$$

Material flow rate in natural tofu processing is the amount of suspense that can be heated in time unit. This statement could be written as steamer capacity or $K_{st} = M_{st}/t$. Steamer capacity is the amount of slurry that can be produce by steamer with heat treatment until boiling. Empirically, steamer capacity could be written as $M_{s/t} = K_{st}$. The equation (10) dan (11) is Black principle for steamer capacity and manual capacity can be express [16]:

$$\frac{Q_t}{t} = \frac{Q_{cs}}{t} = k_e(C\Delta T_a + L) = \frac{M_s C_s (T_2 - T_1)}{t}$$
$$k_e(C\Delta T_a + L) = k_{st} C_s (T_2 - T_1) \quad (9)$$

Manual steamer capacity:

$$k_{st} = \frac{k_e(C\Delta T_a + L)}{C_s(T_2 - T_1)} = \frac{M_s}{t} \quad (10)$$

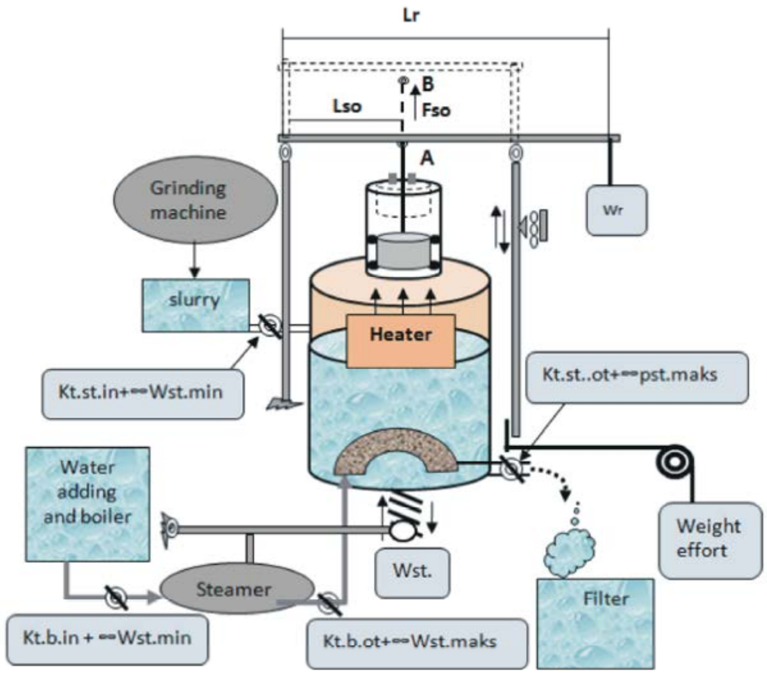

Fig. 2: Construction scheme of steamer equipped with evaporator and continuous burner

The product which is heated inside of steamer is soybean slurry that made by grinding soybean with water. Water specific heat (C_a) mix with dry basis soybean slurry specific heat (C_k) become soybean slurry specific heat (C_s). Each of it has water and soybean moisture. Slurry that is combination of these two formulated as this equation:

$$C_s = k_a C_a + k_k C_k$$

$$C_s = k_a C_a + (1-k_a)C_k \; and \; C_k = \frac{C_s - k_a C_a}{(1-k_a)} \qquad (11)$$

C_s value counted by measurement and C_k value verified by (15):

$$C_k = \frac{1}{n}\sum_{i=1}^{n}\frac{(C_{si} - k_{ai}C_a}{1-k_{ai}} \qquad (12)$$

Next, this value input to manual steamer capacity equation (16) to obtain manual steamer capacity with moisturity variable, so:

$$K_{st} = \frac{k_e(C_a \Delta T_a + L)}{[k_a C_a + (1-k_a)C_k](T_2 - T_1)} = \frac{M_s}{t} \qquad (13)$$

Design characteristic of steamer is the steamer as soybean slurry's heater should be equipped with some supporting component in order to build an automatic system. Steamer and evaporator construction could be built with simple manufacturing technology due to the steamer only work in low pressure and low temperature.

Charateristics of Functional Special Steamer: Evaporator used a conventional boiler and equipped with steam director cover to steamer, as also water filling valve of the evaporator with automatic control by steamer weight changing due to filling and emptying. Main component consist of filter and automatic system equipment such as inlet and outlet valve as shown in Fig. 2.

RESULTS AND DISCUSSION

In this study, the experiment use water as the replacement of soybean slurry inside of the steamer as the material that will be heated. The experiment is done by setting the mass of water inside of the steamer (M_{ast}) in any different weight, 5, 10 and 15 kg, setting themass of pendulum (W_b) in any different weight 2,4 and 6 kg and also the length of time of heating process. The heating time varied depend on water outflowing automatic valve of the steamer I any different weight of the pendulum. Thus, the bigger of pendulum weight influence to the longer heating tike and the higher heating temperature. The heating temperature (T_p) read in these variation. Steamer capacity (k_{st}) is calculated by equation (13), Fig. 2 shows a tofu machine with special steamer that had been made.

Fig. 2: Tofu mahine with special steamer

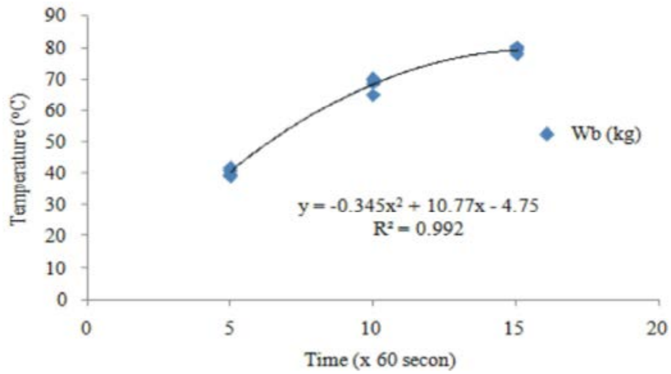

Fig. 3: Correlation of Temperature and the Length on Heating Time

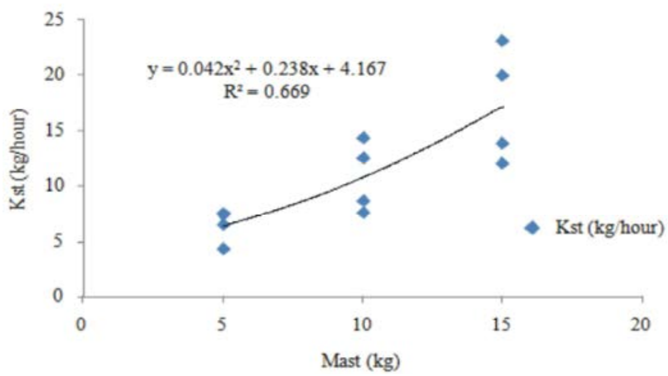

Fig. 4: Steamer campacity in difference water inside.

Table 1: The result of machine test with water

		Experiment results								
		Time (x 60 second)			Temperature (°C)			Steamer capacity (kg/hour)		
Mast (kg)	Wb (kg)	t_1	t_2	t_3	Tp_1	Tp_2	Tp_2	Kst_1	Kst_2	Kst_3
5	2	8	8	8	40	40	40	7.5	7.5	7.5
5	4	18	18	19	70	70	70	4.29	4.29	4.25
5	6	26	26	27	82	81	81	3.66	3.66	3.60
10	2	15	15	15	42	42	41	14.29	14.29	14.29
10	4	26	27	26	69	70	69	8.69	8.60	8.69
10	6	38	38	38	79	79	79	7.59	7.59	7.59
15	2	22	22	21	39	40	40	23.08	23.05	23.05
15	4	35	36	36	65	65	66	13.85	13.90	13.90
15	6	42	42	42	75	75	75	12	12	12

Machine testing is the first step of the steaming phenomenon testing of soybean slurry. This experiment aims to ensure the functional characteristic of the machine by water as the material that will be heated. Table 1 shows the results of tests that have been conducted to see the effect of M_{sat}, W_b, time and temperature to the steamer capacity. Fig. 3 shows, the correlation of the heating time and temperature. Low W_b cause more rapid temperature rise and weight W_b cause temperature rise more slowly, it can be used during the production process to obtain an appropriate comparison between the W_b and the temperature to the planned production capacity.

As the result, it shown in Fig. 3 that the bigger of the pendulum's weight, the heating time is getting longer and the temperature reached is getting higher. The bigger of the weight of water inside of the steamer, the heating time is getting longer but the temperature reached is not significantly different in the using of different pendulum's weight. The value of K_{st} is shown in Fig. 4. The value of the steamer capacity is effect by the mass of water inside of the steamer and the pendulum's weight. The bigger of the the mass of water inside of steamer, on the same value of pendulum's weight, the steamer capacity is getting bigger. The smaller the weight of pendulum, on the same value of water inside of the steamer, the steamer capacity is getting bigger.

CONCLUSIONS

In this paper has been presented the concept of phenomenon of soybean slurry in automatic steamer in the production process of natural tofu. Natural tofu processing machine has been successfully created and tested empirically with its function characteristics of some component has been proved could build an automatic mechanic system. To test the machines that have been created, The experiment is done by setting the mass of water inside of the steamer (M_{ast}) in any different weight, 5, 10 and 15 kg, setting the mass of pendulum (W_b) in any different weight 2,4 and 6 kg and also time of the heating process. The result is low W_b causes more rapid temperature rise and weight W_b cause temperature rise more slowly, it can be used during the production process to obtain an appropriate comparison between the W_b and the temperature to the planned production capacity. Thus, this machine can be used for natural tofu production. It will do more in-depth study and development in the future to get a natural tofu machine with low cost and high efficiency.

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