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## **Developing an Automatic Compression Machine with Multi-level Pressing Distance Adjustment for the Formation of Curd from Milk**

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### **Abstract**

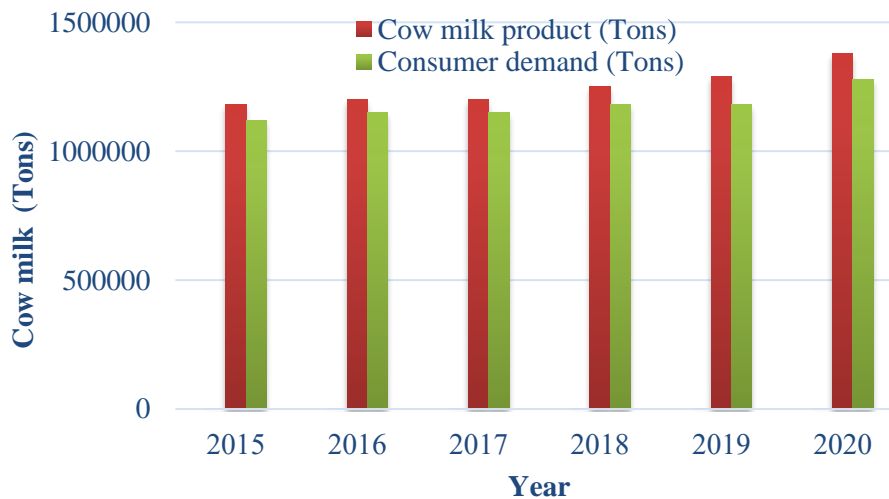
The objectives of this study were (1) to develop an automatic compression machine with multi-level pressing distance adjustment for the formation of curd from fresh milk, (2) to investigate three critical parameters: pressing distance, pressing time, and curd weight, for their effect on the curd formation to find an optimal parameter setting, and (3) to study the impact of the optimized condition for pressing efficiency of the automatic compression machine. The structural simulation method and software were used to create the data set for the optimization process. In this study, the four-level automatic compression machine prototype was developed, and its pressing distance was controlled by the Arduino board to test and investigate the effect of pressing height, pressing time, and curd weight, for their effect on the efficiency of the curd formation. A structure of the machine was made of food-grade stainless steel. The automatic compression machine could be adjusted for the pressing distance within four levels: 20 mm (level 1 control), 30 mm (level 2 control), 40 mm (level 3 control), and 50 mm (level 4 control) by using 100 W brushless DC motor. In this study, the researchers investigated the efficiency of the curd formation by an optimal parameter setting for the machine with 90 mm diameter of circle molding, the impact of pressing distance (20 mm, 30 mm, 40 mm, and 50 mm), pressing time (10 s, 20 s, and 30 s), and curd weight (200 g, 250 g, 300 g, and 350 g). The results showed the optimal settings for these factors: 48 mm for pressing distance (at level 4 control), 30 s for pressing time, and 350 g for

curd weight. Therefore, when compared to the manual curd formation, the machine developed in this study was able to reduce the pressing time by approximately 50 percent.

**Keywords:** *Automatic compression machine, Arduino board, brushless motor, curd*

## 1. Introduction

The cow milk industry is one of the most important industries in Thailand, in which cow milk production tends to increase by 3.07 percentage points during the period between 2016 and 2020, and it increased by 6.77 percentage points between 2019 and 2020 (Office of Agricultural Economic Research, 2020). The cow milk production in the country is increasing every year. Twenty-five percent of cow milk production is used in the school milk project and that of 75 percent is used for commercial milk market. As a result, the demand for domestic consumption is less than that of domestic milk production as shown in Figure 1 (Commodity Trade Office, 2020). Processing of cow's milk products is an alternative to reduce milk oversupply. Processing allows milk to be preserved for longer period and provides a wide range of healthful products including milk, yogurt, and cheese (Bittante et al., 2022).



**Figure 1** Amount of Cow Milk and Consumer Demand

Cow's milk is an outstanding source of imperative nutrients including proteins, vitamins, minerals, and fats. Cow milk proteins comprise 80 percent of casein proteins (CN) and 20 percent of serum proteins (whey proteins), in which the composition of milk protein affects physicochemical, micro-structural, organoleptic, and nutritional properties of dairy products (Tarhan & Kaya, 2021). Currently, cheese is one of the most important dairy products around the world. Various types of cheeses are made from traditional and technological processes including homogenization, pasteurization, evaporation, condensation, hydrolysis, and fermentation.

Food processing uses a variety of technologies to create value-added food products with high product quality and quantity, lower processing cost and energy utilization. In recent years, the technology can also control food processing at the hand of compression, pressing, mixing,

shearing, separation, kneading, flavor generation, filtration or membrane, cooling, pasteurization or heating or sterilization, extrusion, venting moisture, volatility, conveying, shaping, forming, and plasticizing (Prabha et al., 2021; Menis-Henrique et al., 2020).

The filtration process (Ultrafiltration, UF and Microfiltration, MF/diafiltration) is selected to enrich fresh milk with protein powders containing milk protein or micellar casein (Warncke et al., 2022; Kelly et al., 2008; Guinee et al., 2006); while cheese-making is a concentration of milk and biological transformation of milk compositions into gustatory and aromatic components (Chitchyan and Grigoryan, 2016). The cheese making process consists of five steps: standardization, pasteurization, rennet coagulation, curd firming, curd-whey separation, and extrusion. Cow milk cheese is preferred by consumers and can compete in the market of commercial cheese.

A compression or extrusion process is a commonly used kneading and formation of curd and cheese to decrease force and time due to the usability of mechanical force. However, the extrusion process is very expensive; consequently, the process is not economically viable. Therefore, the objectives of this study were to (1) develop the automatic compression machine with multi-level pressing distance adjustment for the formation of curd from fresh milk, (2) investigate the critical parameters for their effect on the curd formation to find optimal parameters setting, and (3) study the impact of the optimized condition for pressing efficiency of the automatic compression machine.

## 2. Methodology

### 2.1 Materials and Reagent

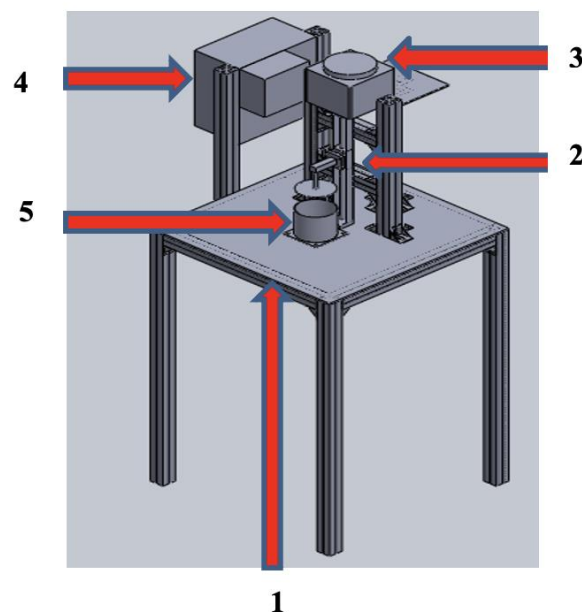
The researchers used raw cow milk delivered from Pranburi, Prachuap Khiri Khan Province, Thailand, and suddenly pasteurized it at 72 °C for 17 s and then cooled to 3 °C. The milk was also stored at 3 °C for the preparation of curd production. Reagent was used with rennet powder for the coagulation process, which contains a chymosin enzyme 100 %. Rennet was stored at 4 °C for curd production.

### 2.2 Experimental Setup

In this study, the researchers used an experimental setup to develop the automatic compression machine with multi-level pressing distance adjustment for the formation of curd from fresh milk. The automatic compression machine consists of five parts: (1) the upper part of structure made of aluminum (60 cm of width, 60 cm of depth, and 100.5 cm of height); (2) the ball screw drive system made of aluminum (20 cm of depth, and 48 cm of height); (3) the mechanical drive system with brushless DC motor applied to constant speed in extrusion, in which shaft and ball bearing are used to support load and reduce rotational friction; (4) microcontroller system with circuit breaker, Arduino Mega 2560, board drive, blister, relay module, 12C LCD display, switching power supply, and emergency stop switch, in which the compression distance was controlled by programming C<sup>++</sup> of Arduino microcontroller; and (5) the cylinder mold made of food-grade stainless steel (304) (1 mm of thickness, 100 mm of diameter, 120 mm of width, and 120 mm of height). These five parts are shown in Figure 2.

## 2.3 Curd Production

The researchers conducted a curd production in a 60 L with a working volume of 10 L; the pasteurized milk (10 L) was warmed to 35 °C in a pilot-scale stainless steel machine at 15 min. Chymosin enzyme rennet was added at 0.5 g, in which agitation speed and time were maintained at 15 rpm and 30 s. Rennet was used for the formation of a gel matrix of casein from milk (Davuddin et al., 2022; Fox et al., 2015). The temperature was then gradually raised from 35 °C to 40 °C for 30 min and the curd was cut approximately into 1 cm<sup>3</sup>. Finally, the curd and whey milk were filtered via strained to remove fine residual particles of curd. Forty-eight samples of 200-350 g of curd with the automatic compression machine prototype, were conducted in 10-30 s of pressing time, with four levels of pressing distance (Levels 1-4: 20-50 mm) to investigate these parameters for their effect on the pressing efficiency of the curd formation, hereafter referred to as SC1-SC48, respectively.



**Figure 2:** Automatic Compression Machine with Multi-level Pressing Distance Adjustment, where (1) Upper Part of Structure, (2) Ball Screw Drive System, (3) Mechanical Drive System, (4) Microcontroller System, and (5) Mold System

## 2.4 Analytical Methods

In this study, the formation of good shape of curd was used to indicate conditions well-suited for the optimal parameters setting of the machine. Besides, the curd formation was also used for identifying the pressing distance and for calculating the pressing efficiency of the machine as well.

## 3. Results

### 3.1 Effects of Curd Weight, Pressing Distance, and Pressing Time on Curd Formation

The formation of curd is presented in Table 1. It can be seen that the curd weight depends mainly on the pressing distance and the pressing time. The formation of curd was in 5 types as follows: A (the formation of curd in good shape), B (the formation of curd stabilized in longer pressing time than 10 s), C (the formation of curd relatively stable in a short time), D (the formation of curd overflowing the mold), and F (the cap of mold not pressable into the curd). The experimental results showed the similar conditions for curd formation with Levels 1-4 of pressing distance, in which an optimal condition was observed in (1) SC3 (200 g of weight and 30 s pressing time), (2) SC18 (250 g of weight and 30 s pressing time), (3) SC33 (300 g of weight and 30 s pressing time), and (4) SC48 (350 g of weight and 30 s pressing time), respectively. Pressing and heating occurred in the process in which water was released from the casein protein, resulting in increased dry matter for longer shelf life (Schmidt et al., 2022). Therefore, this result was explained by an intensive compression mechanical treatment of curd formation before producing mozzarella cheese, which can be used as the optimal condition.

**Table 1:** Effects of Curd Weight, and Pressing Time at Levels 1-4 of Pressing Distance Control on Curd Formation

Sample	Curd weight (g) and pressing time (s) at Level 1 (20 mm of pressing distance control)	Curd formation	Sample	Curd weight (g) and pressing time (s) at Level 2 (30 mm of pressing distance control)	Curd formation
SC1	200:10	C	SC13	200:10	F
SC2	200:20	B	SC14	200:20	F
SC3	200:30	A	SC15	200:30	F
SC4	250:10	D	SC16	250:10	C
SC5	250:20	D	SC17	250:20	B
SC6	250:30	D	SC18	250:30	A
SC7	300:10	D	SC19	300:10	D
SC8	300:20	D	SC20	300:20	D
SC9	300:30	D	SC21	300:30	D
SC10	350:10	D	SC22	350:10	D
SC11	350:20	D	SC23	350:20	D
SC12	350:30	D	SC24	350:30	D
SC25	200:10	F	SC37	200:10	F
SC26	200:20	F	SC38	200:20	F
SC27	200:30	F	SC39	200:30	F
SC28	250:10	F	SC40	250:10	F
SC29	250:20	F	SC41	250:20	F
SC30	250:30	F	SC42	250:30	F
SC31	300:10	C	SC43	300:10	F
SC32	300:20	B	SC44	300:20	F
SC33	300:30	A	SC45	300:30	F
SC34	350:10	D	SC46	350:10	C
SC35	350:20	D	SC47	350:20	B
SC36	350:30	D	SC48	350:30	A



A: The formation of curd in good shape.



B: The formation of curd stabilized in longer pressing time than 10 s.



C: The formation of curd relatively stable in a short time.



D: The formation of curd overflowing the mold.



F: The cap of mold not pressable into the curd.

### 3.2 Pressing Efficiency of Curd Samples of the Automatic Compression Machine

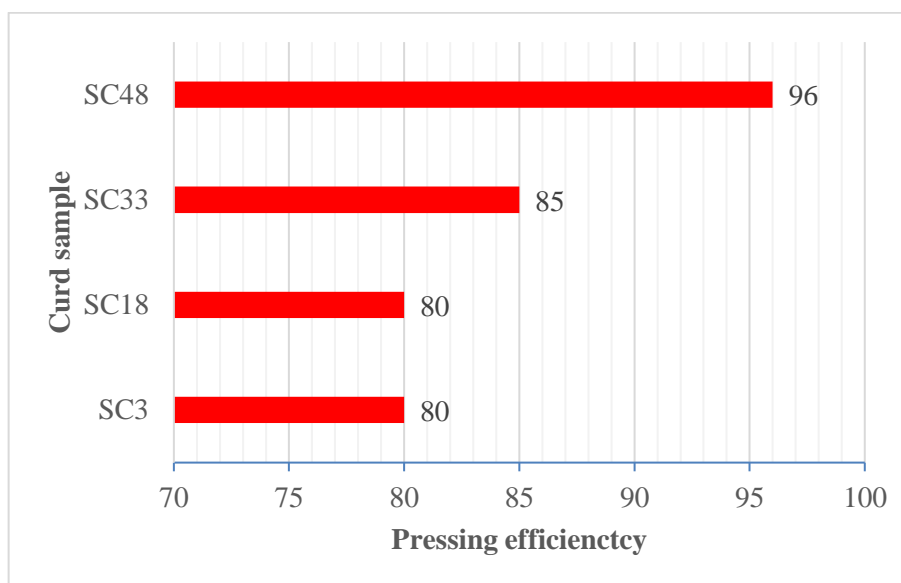
The curd weight was greatly influenced by the presence of the pressing distance, as shown in Table 2. Curd formation of four samples presented good shape (A) of SC3, SC18, SC33, and SC48 with an optimal condition of curd weight (30 s of pressing time) for all pressing distance control. The four samples underwent pressing in different conditions, in which curd weight of SC3, SC18, SC33, and SC48 were 200 g, 250 g, 300 g, and 350 g, respectively, for 20 mm, 30 mm, 40 mm, and 50 mm of pressing distance control. The results in a pressing distance curd were observed at 16 mm (Level 1), 24 mm (Level 2), 34 mm (Level 3), and 45 mm (Level 4) of SC3, SC18, SC33, and SC48, respectively. A significantly positive interaction between the pressing distance control and the curd weight at the same pressing time was also observed. To the

researchers, it was possible to observe the higher pressing distance control and curd weight in yielding higher pressing efficiency (see Figure 3). Pressing efficiency percentages of SC3, SC18, SC33, and SC48 were 80 %, 80 %, 85 %, and 96 %, respectively. It can be concluded that SC48 (the highest of curd weight and pressing distance) indicates the ability of the compression process on food processing as the highest among all samples.

**Table 2:** Pressing Distance and Pressing Efficiency Results of Curd Samples

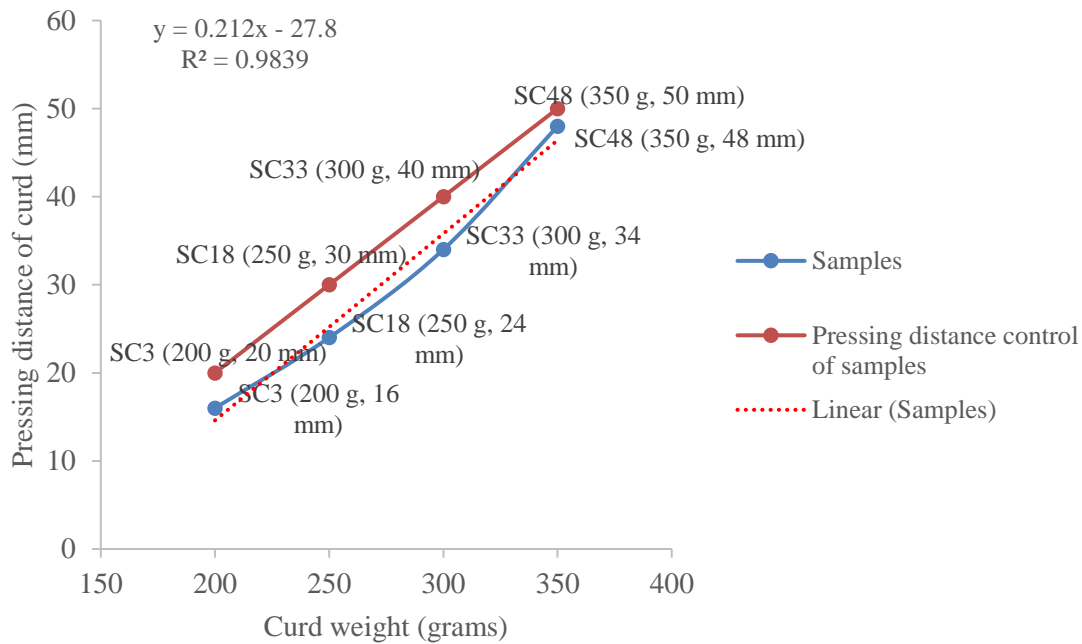
Sample	Curd weight (g)	Pressing distance of curd (mm)	Pressing distance control (mm)	Pressing time (s)	Curd formation	Pressing efficiency
SC3	200	16	20 (Level1)	30	A	80
SC18	250	24	30 (Level 2)	30	A	80
SC33	300	34	40 (Level 3)	30	A	85
SC48	350	48	50 (Level 4)	30	A	96

A: The formation of curd in good shape.



**Figure 3:** Pressing Efficiency of Curd Samples

Finally, the curd weight and the pressing distance for each sample at Levels 1-4 (30 s of pressing time) results with varying accuracy, of which the degree of fitness is indicated by  $R^2$  in Figure 4. It was found that it could be seen high  $R^2$  value ( $> 0.95$ ) for pressing distance control, and curd weight. This means that the pressing distance developed for each sample should provide an accurate result, when curd weight and pressing time are related to the formation of curd.



**Figure 4:** Comparison of Pressing Distance Result and Pressing Distance Control for Curd Sample

#### 4. Conclusion and Discussion

This study reports an automatic compression machine developed with multi-level pressing distance adjustment for the formation of curd from fresh milk. The researchers also investigated three critical parameters including pressing distance, pressing time, and curd weight, for their effect on the curd formation for an optimal parameter setting of the automatic compression machine. A setup for curd formation was presented, while the desired pressing distance and curd weight of the experiment were successfully shown at 16 mm (Level 1), 24 mm (Level 2), 34 mm (Level 3), and 48 mm (Level 4) with 200 g, 250 g, 300 g, and 350 g at 30 s pressing time, respectively. Pressing efficiency of SC33 and SC48 of the machine was higher than 80 %. The SC48 was observed as 96% of the highest pressing time in efficiency. It was the best result for curd formation from the developed automatic compression machine. The control shown in the study could lead to improvement in cheese production in both quality and quantity.

Further research should focus on the characterization of curd products and cheese curd production as well as that of compression for product properties, particularly the effect on chemical properties. Moreover, interested researchers could aim at economic analyses in the use of the automatic compression machine for cheese production.

#### 5. Acknowledgement

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## 6. The Authors

Five authors of this paper shared their research interest in the integrated areas of mechatronics engineering, industrial technology, nutrition, food processing, curd formation from milk, automatic compression machine development, and multi-level pressing distance adjustment. Three authors Kodchasorn Hussaro, Teerayut Luengsriskul, and Nisakorn Somsuk are from Rajamangala University of Technology—the first two from Rattanakosin, Salaya Campus and the third from Thanyaburi Campus. The other two authors: Jutiporn Intanin works in the area of engineering and industrial technology, and Pornariya Chirinang in applied food and nutrition—both at Phetchaburi Rajabhat University, Thailand.

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