RESULTS OF TECHNOLOGYCAL PARAMETERS OPTIMIZATION FOR THE CURD FILTER – PRESSING EQUIPMENT
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ААРЦ ШАХАХ ТӨХӨӨРӨМЖИЙН ТЕХНОЛОГИЙН ҮЗҮҮЛЭЛТИЙГ ОНОВЧИЛСОН ДҮН

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ABSTRACT
Mongolia has a large nomadic culture which has existed for thousands of years. Nomadic herders spend much of their time producing milk and dairy products, including Aaruul, or dried yogurt curd, which is a local dairy product unique to Mongolia. There are several steps in the production of Aaruul from raw milk to the final dried curd, including an overnight filtration process. The main objective of this study was to optimize the curd filter pressing process for a newly designed apparatus, to establish the best time, pressure and weight of the curd. The apparatus tested could halve the time of current filtration methods. This study also demonstrated a more precise mathematical model of operating parameters of the pneumatic filter pressing device, measuring curd weight, compression pressure and time.

ХУРААНГУЙ
Монгол улс олон мянган жилийн турш оршин тогтнож ирсэн нүүдэлчдийн томоохон соёлтой. Нүүдэлчин малчид сүү, сүүн бүтээгдэхүүн, түүний дотор ааруул буюу хатаасан тарагны ааруул үйлдвэрлэхэд ихээхэн цаг хугацаа зарцуулдаг бөгөөд ааруул нь Монгол орны өвөрмөц онцлогтой орон нутгийн сүүн бүтээгдэхүүн юм. Түүхий сүүнээс эцсийн бүтээгдэхүүн болох ааруулыг хийхэд хэд хэдэн шат дамжлагатай байдаг. Энэхүү судалгааны ажлын гол зорилго нь шинээр зохион бүтээсэн төхөөрөмжийн аарц шахах процессыг оновчтой болгох, аарц шахах хамгийн тохиромжтой хугацаа, даралт, жинг тогтоох явдал байв. Туршилт хийсэн төхөөрөмж нь аарц шахах уламжлалт аргын хугацааг хоёр дахин багасгах боломжтой. Хийн шахуурга бүхий аарц шахах төхөөрөмжийн ашиглалтын үзүүлэлтүүд болох аарцны жин, шахах даралт, хугацаа зэргээс хамааруулан аарцны чийгийг тодорхойлон, математик загвар гаргаж, оновчтой утгуудыг тогтоолоо.

INTRODUCTION
Traditional Mongolian dairy products are consumed not only as important energy sources, but as traditional medicines *(Takeda et al., 2013; Won-Young Cho et al., 2020).* Dairy products are an important source of everyday nutrition for Mongolians. For generations, herders have been making dairy products from raw milk from their cattle using conventional home methods. Mongolians widely use high-protein dried curds that are well suited to the needs of people living in the arid climates of Central Asia (*Indra, 1983)*. Dried curd (Aaruul) is made of curdled milk that has been air-dried in direct sunlight. It is consumed as a snack, is sometimes flavored with sugar and berries, and has a long shelf-life which is perfectly suited to the nomadic lifestyle (*Daginger, 2015*). The composition of Mongolian cow milk varies depending on geographical location and type of plant species livestock consume (*Narangerel and Narangerel, 2009*).

According to the National Statistics Office the average annual consumption of dairy products per capita, between 2014 and 2017 had reduced from 415.45g per day to 136.5g per day or 67.1% in the capital city and from 667.6g per day to 380.9g per day or 42.9% in the country side *(Indicators for food security statistics, 2014; Indicators for food security statistics, 2017).*

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In 2018, the number of herder households decreased by 37 and the percentage of herders decreased by 4.9% compared to the previous year in Mongolia (*Indicators for food security statistics,* 2018). At the same time, the consumption of dairy products has fallen year by year, and 50% of the total dairy consumption has been supplied by imported products *(Indicators for food security statistics, 2017)*. Cattle farming is hard job due to the fact that it depends on weather and grasslands. So, to bring innovative technologies to increase efficiency of dairy products for cattle farming is essential.

Every herder households are able to supply certain percentage of dairy products by processing their milk and dairy products in summer and fall using modern techniques under traditional technologies. The aaruul (shaped and dried curd) making process, including curd filter pressing and drying, takes 4-5 days since the beginning.

Aaruul is one of the protein dairy products and as a Standard of general technical requirements (MNS 4230:2005), dairy protein contains not less than 14 per cent of the total protein derived from milk casein protein and whey milk produced by conventional and industrial methods. Table 1 describes some physical and chemical properties of curd products. As noted, the technical requirements for curds, which are a type of protein milk, are slightly sour or sweaty, have their own truly unique flavors, white or light yellow color, free from whey milk and even medium density *("Standards of general technical requirements for protein dairy. MNS 4230:2005", 2005).*

Table 1

Physical and chemical properties of curd products

Type of protein products	Parameters				
	Moisture, not less than %	**Protein,** %	**Fat,** %	**Sweetness,** %	**Acidity,** °T
Curd and curd's product	55.0	14.0 – 25.0	0.5 – 18.0	1.5 – 25.0	200 – 270
Aaruul	10.0 – 20.0	30.0 – 40.0	0.5 – 30.0	2.0 – 30.0	180 – 270

Numerous scientific studies have been conducted on the physical and chemical properties of dairy products and their use, composition and structure.

As noted in the scientific basics of Mongolian industrialized technology of dairy products, Damdinsuren et al. pointed out that the technology of curd filtration was suitable at a temperature of 90-95°C *(Damdinsuren, 2002).*

However, no research has been done on techniques and equipment for curd filter pressing, in particular on compression. Simplification of herder milk treatment, especially curd filter - pressing, curd forming and drying, will increase the efficiency of production and consumption of dairy products. Families are able to sell them on the market to expand profits and contribute to the growth of their household businesses. The aim of this study was therefore to design a curd filter - pressing machine for herder households and to determine the optimum values of the main parameters.

MATERIALS AND METHODS

Tsagaa (boiled yogurt) was made from cow milk under domestic conditions and curds were obtained and used for compression experiments *(Indra, 1983).* After the yogurt was boiled and cooled, it was placed in a cloth bag, the whey milk was drained, and it was prepared for the filter pressing test.

In August, measured portions of 400 liters of cow milk from a herder household of Batsumber soum, Tuv aimag were used in the research.

In the case of a herder household, the filtered curd is placed between two plates, pressed with a load of 20 to 30 kg for 12 hours to release the whey. To facilitate this operation, a pneumatic pump experimental machine was developed and a curd pressing test was carried out.

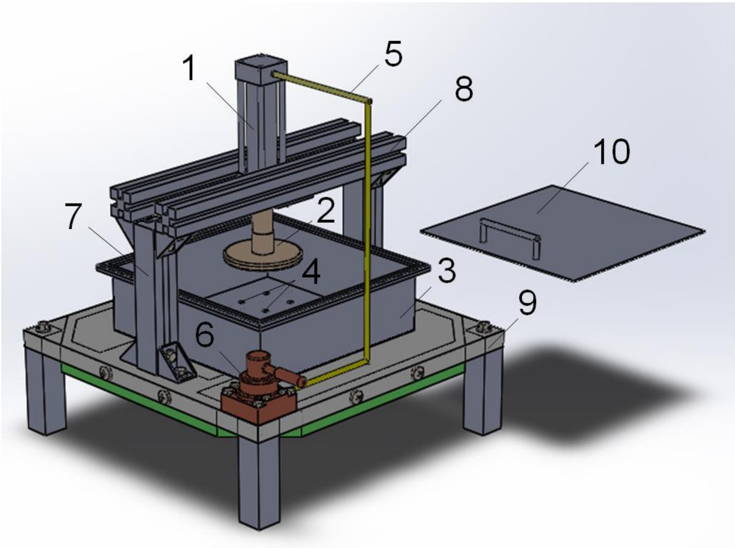

Fig. 1 - Curd pressing device with air pump

1 – pneumatic cylinder, 2 – pressing plate, 3 – drainage vessel, 4 – whey drainage holes, 5 – plastic tube, 6 – hydraulic valve, 7 – vertical pillar, 8 – horizontal pillar, 9 – base platform, 10 - square lid

The curd filter pressing experiment was performed using the method of planning and experiments for multi factor parameters. The mathematic statistic processing had to be done by the results of experiments to create the mathematical model of multivariate regression.

The general model of the second-order regression equation for the three factor experiment can be written as follows for the curd filter pressing:

$$y_i = b_o + b_1x_1 + b_2x_2 + b_3x_3 + b_{12}x_1x_2 + b_{13}x_1x_3 + b_{23}x_2x_3 + b_{11}x_1^2 + b_{22}x_2^2 + b_{33}x_3^2 \quad (1)$$

where: $b_o, b_1, \cdots b_{33}$ – equation coefficients; x_1, x_2, x_3 – factors

The effects of the regression coefficients of the mathematical model can be tested according to the T critical value:

$$t_T = (b_i) = \frac{|b_i|}{\sigma\{b_i\}} < t_x \quad (2)$$

where: t_T – calculated T critical value, t_x – T critical value, b_i – regression coefficient, $\sigma\{b_i\}$ – average squared deviation.

The similarity of the regression model can be tested by F distribution:

$$F_T = \frac{\sigma_{sim}^2\{y\}}{\sigma^2\{y\}} < F_x \quad (3)$$

where: F_T – Calculated F critical value, F_x – critical value of F distribution, $\sigma_{sim}^2\{y\}$ – value of the dispersion of similarity when repeated at the main test point, $\sigma^2\{y\}$ – dispersion of outlet parameter.

The optimal values of the multi-factored model was determined with the minimum values of the input factors as reported by Avdai and Enkhtuya (*Avdai and Enkhtuya, 2017*).

RESULTS & DISCUSSION

In order to select a suitable material for curd compression, the curd was prepared using the traditional method which was applied to three different commonly used bag fabrics of the same size, filtered and pressed at the same time.

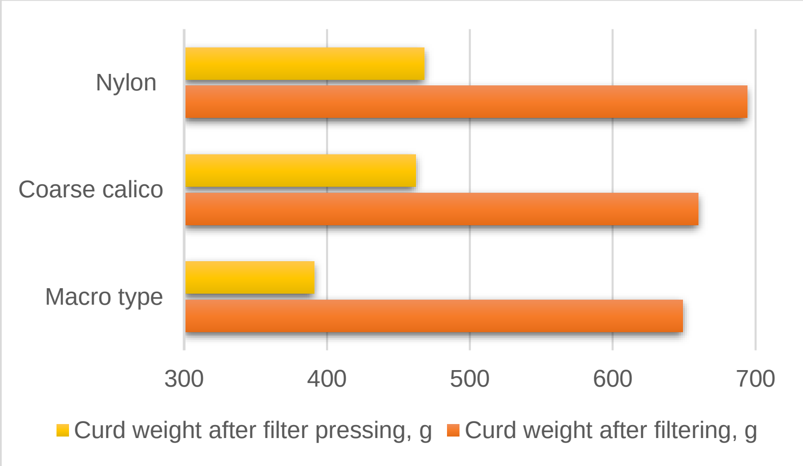

Fig. 2 – Curd weight after filtering and pressing, by three different materials

As seen in Figure 2, after filtration, the curd weight with nylon bag was 6.5% higher than the curd weight with macro type bag and 2.7% higher than that of the curd weight with coarse calico bag. Otherwise, nylon material has pretty poor filtration or less leakage.

After pressing, the weight of the curd with nylon material was 16.4% greater than the curd weight with macro type bag and 2.7% more than the curd weight with coarse calico bag .

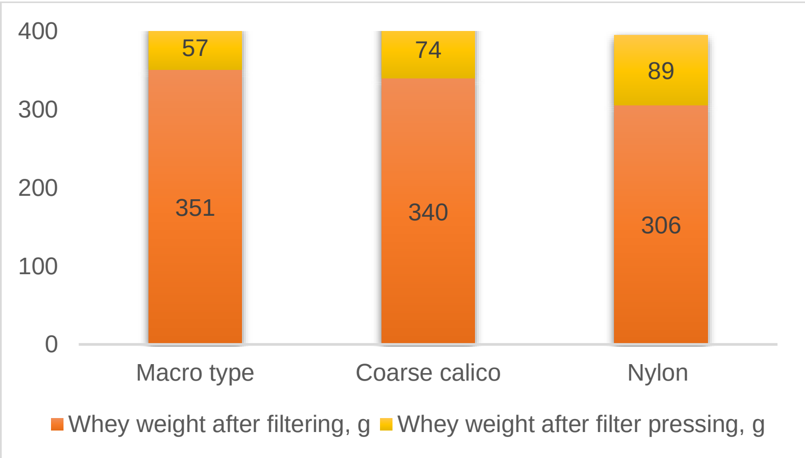

Fig. 3 – Whey weight after filtering and pressing

As shown in Figure 3, during the filtration process, more whey was released from the macro type of texture bag than from other bags, but more of the whey was discharged from the nylon bag than other bags during the pressing process. Even still, the highest release of whey was found when the coarse calico bag was used for both operations with 414 g of 1000 g curd. The coarse calico bag was therefore chosen for further experiments with a filter pressing machine. Honeycomb type cotton is a material used to pack the curd of cheese and it was determined that the porous material with pores of 2.67 mm^2 can be used too *(Oyunjargal, 2010)*. The general design of the objectives of the main parameters for the operation of the machine was chosen as follows in Figure 4.

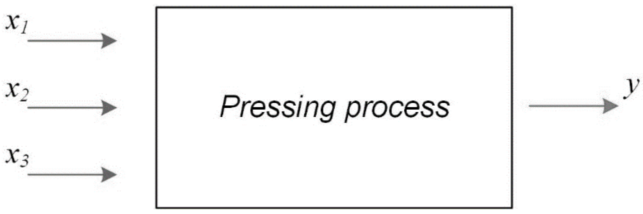

Fig. 4 – General design of objectives

Inlet parameters: x_1 – curd weight; x_2 – pressure; x_3 – duration; outlet parameter: y– curd moisture, %.

$$y = f(x_1, x_2, x_3) \rightarrow 55 - 80\%$$

Parameter levels that represent y-value are determined not only by the values of X_{imax}, X_{imin}, but by box planning or second-order rotatable planning with 3rd and 5th grade changes *(Avdai and Enkhtuya, 2017).* Optimum values of the inlet parameters are defined by the preliminary tests as demonstrated in Table 2.

Table 2

Experimental conditions

Effective parameters	Changed values of effective parameters					J_i
	$-x_a$	x_{imin}	x_{i0}	x_{imax}	$+x_a$	
	-1.682	-1	0	+1	+1.682	
Curd weight X_1, kg	0.182	2	2.5	3	4.682	0.5
Filter pressing pressure X_2, kg cm^{-2}	1.318	3	4	5	6.682	1
Duration X_3, min	118	120	150	180	181.682	30

The moisture content of the filter pressed curd must not be less than 55% as shown in Table 1.

The moisture value of the filter pressed curd is determined by the standard 'Method for the determination of moisture and dry matter in milk and milk products' MNS 401: 75 *("Standard of method for determination of moisture and dry matter in dairy products. MNS 0401:1975", 2009)*. The data obtained from the curd pressing experiment in the filter cloth are presented in table 3.

Table 3

Experimental matrix and the results

№	Standard matrix			Experimental matrix			Outlet parameters
	Inlet parameters			Real values of inlet parameters			
	x_1	x_2	x_3	X_1	X_2	X_3	y
1	-	-	-	2	3	120	66.6
2	+	-	-	3	3	120	66.6
3	-	+	-	2	5	120	64.6
4	+	+	-	3	5	120	64.4
5	-	-	+	2	3	180	62
6	+	-	+	3	3	180	65.3
7	-	+	+	2	5	180	59.4
8	+	+	+	3	5	180	62.9
9	-1.682	0	0	0.182	4	150	57.8
10	+1.682	0	0	4.682	4	150	68.3
11	0	-1.682	0	2.5	1.318	150	69.6
12	0	+1.682	0	2.5	6.682	150	64.25
13	0	0	-1.682	2.5	4	118	63.2
14	0	0	+1.682	2.5	4	181.682	59.4
15	0	0	0	2.5	4	150	58.9
16	0	0	0	2.5	4	150	60.2
17	0	0	0	2.5	4	150	64.1
18	0	0	0	2.5	4	150	65.3
19	0	0	0	2.5	4	150	62.5
20	0	0	0	2.5	4	150	64.7

The mathematical processing of the numerical values of the measurements was governed by the law of normal distribution, and the calculated value of the $Shapiro\ and\ Wilka\ W$ criteria was $W_T = 71.23$, which allowed the value in the table to be greater than $W_X = 0.96$. The calculated value of the $Cochrane$ criteria G, $G_T = 0.203$ is less than that of the table, $G_X = 0.2705$, indicating that the dispersion is homogeneous. Regression coefficients for factor dependence has been determined and a multivariate regression model (eq.4) for dependence has also been obtained.

$$y = 62.5494 + 1.9516x_1 - 1.3321x_2 - 1.3902x_3 + 1.5667x_2^2 - 0.4228x_3^2 \quad (4)$$

When the regression model was tested by Fisher's test, the calculated value of the test was $F_T = 0.56$, and $F_T < F_X = 2.71$, so our model proved to be similar.

We put following values to obtained regression model and defined the real model (eq.5):

$$x_1 = \frac{X_1 - 2.5}{0.5};\ x_2 = \frac{X_2 - 4}{1};\ x_3 = \frac{X_3 - 150}{30}$$

$$y = 79.546 + 3.903X_1 - 13.858X_2 + 0.095X_3 + 1.565X_2^2 - 0.00047X_3^2 \quad (5)$$

Figure 5 shows the correlation of the curd moisture (y) from the curd weight (X_1) and the pressure of the pressed curd.

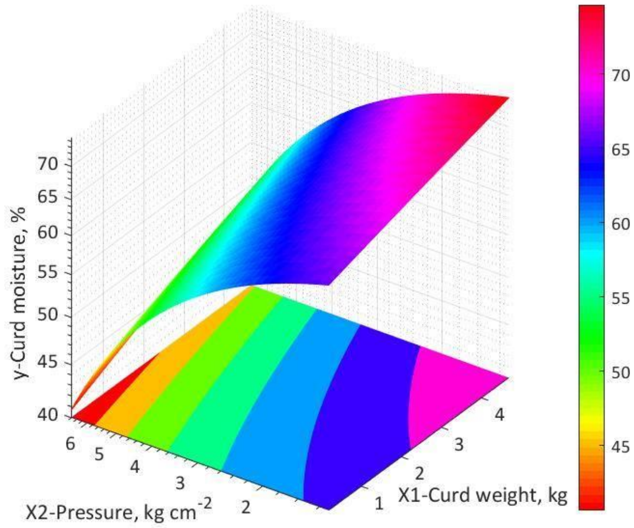

Fig. 5 – The moisture reflecting surface of pressed curd and its correlation graph $y = f(X_1, X_2)$

It shows that when the pressure (X_2) increases, the curd moisture (y) declines, when the curd weight (X_1) rises, the curd moisture (y) increases, respectively. The maximum value of the pressure (X_2) and the minimum value of the curd weight (X_1) can be seen in Figure 5 to hold the curd moisture (y) at between 55 – 60%.

Figure 6 shows how the pressed curd moisture (y) changes by the variation of curd weight (X_1) and pressing time (X_3).

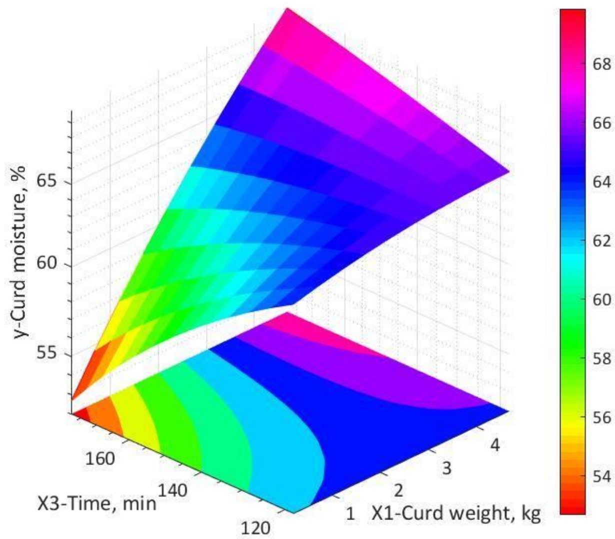

Fig. 6 – The moisture reflecting surface of pressed curd and its correlation graph $y = f(X_1, X_3)$

The Figure 6 describes that when the pressing time (X_3) increases, the curd moisture (y) decreases and when the curd weight (X_1) increases, the curd moisture (y) increases, respectively. To hold the curd moisture (y) in-between 55 – 60% the minimum value of the curd weight (X_1) and the maximum value of the curd pressing time (X_3) can be observed in Figure 6.

As presented in Figure 7, the pressed curd moisture (y) changes due to the variation of the curd pressing pressure (X_2) and the pressing time (X_3).

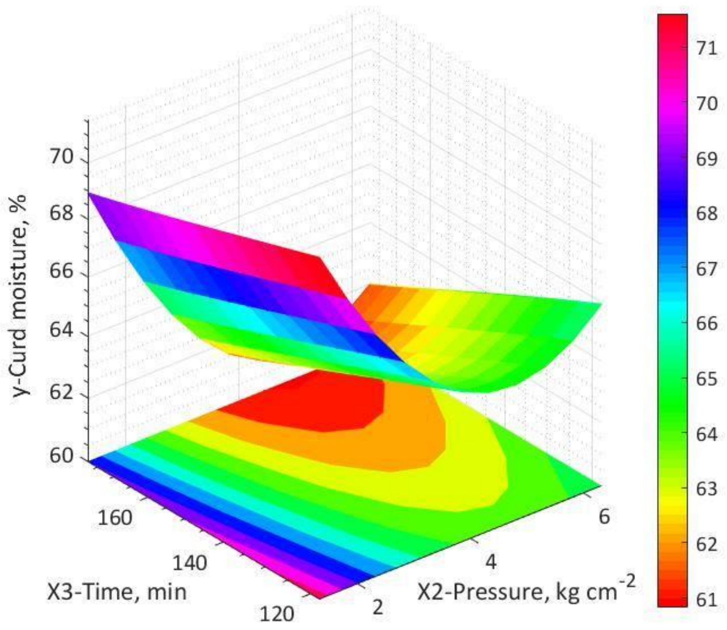

Fig. 7 – The moisture reflecting surface of pressed curd and its correlation graph $y = f(X_2, X_3)$

Figure 7 demonstrates that when the pressing pressure (X_2) and the curd pressing time (X_3) increases, the curd moisture (y) decreases. When the curd moisture content is (y) between 55-60 percent, the maximum value of the curd pressing pressure value (X_2) and the curd pressing time (X_3) could be seen in Figure 7.

By dissociative steps method, the optimum inlet values, when the outlet value is at minimum level, are determined from the real model and the results are shown below $X_1 = 2\,kg,\ X_2 = 5\,kg\,cm^{-2}, X_3 = 180\,min,$ curd moisture $y = 59\%$. Oyunjargal and her team has developed a model of the cheese pressing process and studied the process of cheese formation rheology and structure. According to the results of this study, the method of liquid pressing used was 8 times shorter in terms of time compared to traditional methods of cheese pressing *(Oyunjargal, 2010)*.

CONCLUSIONS

In the experiment of selecting a convenient material for filtering and filter pressing of curd prepared by conventional method, the highest whey milk releasing material was coarse calico.

Based on the specific moisture content, the values of weight, filter pressure and pressing time using the air pump for curd pressing have been optimized and the mathematical model has been defined. The pressure and weight values were determined as the most effective parameters during the experiments.

The optimal values of the inlet parameters of the curd filter pressing process are calculated as 2 kg of curd weight, 5 kg cm^{-2} (0.49 MPa) of pressing pressure and 3 hours of pressing time to be 59% of the curd moisture content. The moisture content of the curd is 59%, which meets the requirement for moisture content of protein dairy products.

The results show that we are able to reduce the filter pressing time by half compared to the traditional method by using a machine. The machine was invented to save the time and human labor for curd making process. It can be seen that the time required for herder households to filter pressing curd can be halved and the productivity of curd production can be increased.

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