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Application of High Electric Field Pulses in Coconut Milk Processing

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***Abstract* – The aim of this study was to investigate the application of high electric field pulses (HELP) as a non-thermal cell disintegration method for production of coconut milk and separation of coconut oil from coconut milk. The results of this study showed that it is possible to increase the coconut milk yield using HELP pretreatment (at 4.25 kV/cm and 163 pulses, energy consumption less than 10kJ/kg) compared to the thermal method (80 °C, 15 min, energy consumption of about 200 kJ/kg). The yield of coconut milk using HELP treatment was distinctly higher (79.68%) than untreated (74.03%) and slightly higher than thermal (78.14 %) or freeze thaw (82.20%) pretreated samples. In addition, the oil content in HELP pretreated coconut milk was higher (24.5%) than untreated (18.5%) and comparable or slightly lower than heat treated or freeze thawed samples (24% and 25 % respectively).**

High electric field pulse treatment of coconut cream at 3kV and 150 pulses followed by centrifugation (4000 rpm, 10 min) resulted in a drastic increase of oil separation (30.81%) compared to centrifuged samples without HELP treatment (11.75) and comparable (32%) oil separation with thermal (at 90 °C, 10 min) treated sample. In general energy consumption for oil separation using HELP treatment was distinctly lower (about less than 80 kJ/kg) compared to thermal treatment (about 250 kJ/kg, at 90 °C.

***Keywords* – Coconut Milk, Oil Separation, High Electric Field Pulse, Cell Permeabilization**

I. INTRODUCTION

In Thailand, almost 1,721,640 metric tons of coconut was produced in 2009. Coconut could be processes into various products and one such example is coconut milk: a white milky product extracted from the endosperm of coconut.

Coconut milk serves as a significant dietary ingredient in coconut producing countries and it is used in various diets as flavor enhancer [1]. There are numerous research works on conversion of coconut milk into various other products such as dehydrated coconut milk[20, dehydrated skim coconut milk [3], and canned coconut cream [4]. The application of enzymes and heat treatment for coconut processing are reported by [5]. Other researchers [6] worked on the extraction of oil from coconut milk press cake. The Application of natural enzymes from pineapple for enhanced coconut milk extraction was studied by [7]. There are many opportunities for use of coconut for development of new products or for use in other food formulations such as dried coconut to obtain copra from which coconut oil is produced. The yield of coconut milk in conventional pressing methods is low. Thus, it is important to develop new methods to increase coconut milk yield.

HELP processing is an exciting emerging technology that offers not only potential for the preservation of food materials, but also can be utilized effectively for the modification of food materials [8]-[9]-[10]. Moreover, it can be applied successfully for specific treatment of cellular materials such as plant tissues [11]. However, substantial research and development activities are still required to understand, optimize, and apply this complex process to its full potential. HELP treatment of plant tissues requires very low energy (less than 15 kJ/kg) compare to thermal treatment (about 250 kJ/kg at 90 °C) of plant tissue to achieve maximum permeabilization and the temperature increases observed during such treatments are almost negligible [12].

The evident advantages of electrical treatment applications in the food industry are simplicity, no requirement for any complex or expensive equipment, gentle technique (only a few seconds for processing), and no thermal degradation of food nutrients. This method can be easily applied in combined mode as supplementary to any processing [12]. The ability of HELP to destroy cell membranes and enhanced mass transfer has been used in several applications. Beginning with Flaumenbaum [13], an electrical treatment of apple mash achieved an increase in yield of about 10 to 12%. Further yield enhancement was achieved with treatment on carrot juice [14], red beet juice [15], sugar beet juice, grape, sugar cane, and apple [16]-[17]-[18]-[19].

The HELP application involves the use of an electric field at 5 - 10 kV/cm for 0.1 -10 µS at room temperature, which can be a good alternative against traditional thermal treatment methods for plant cell tissue treatment [20].

High electric field pulse (HELP) could be used as pretreatment method in the processing of coconut milk by breaking the cells in coconut meat. Ref. [1] studied the effect of process parameters during high electric field pulses on cell permeabilization and yield of coconut milk. Treatment with HELP under suitable conditions (2.5 kV/cm, n=20 pulses, pulse width of 575 µS) resulted in 20 % increase in milk yield with reference to the untreated samples. The fat contents of the extracted milk from HELP treated samples were higher than untreated samples. In additions, they could achieve up to 22% shorter drying time of coconut meat after HELP pretreatment compared to untreated sample.

In general, coconut oil could be extracted by using a high energy consuming centrifuges to separate oil from coconut milk. The separation of coconut oil from coconut milk by centrifugal method requires high electrical energy and takes long time. It is also interesting to investigate the effect of high electric field pulse (HELP) for phase separation of coconut milk to save energy and time.

The aims of this study were to investigate the effect of process parameters during HELP treatment on yield and contents of coconut milk as well as separation of coconut oil from coconut milk using HELP technique.

II. Material and Methods

A. Raw material

Fresh coconut from market (Nakhorn Pathom, Thailand) was used for this project. The brown skin of Coconut meat was removed using a sharp knife and the meat (white meat) was ground in small rasp (about 5 mm long and 2 mm edge length).

B. Equipment

For high electric field pulse treatment a laboratory scale h igh electric field pulse generator (max. 7 kV, 4µF, 1.5 KW, 1Hz pulse frequency), designed and built at Mahidol University, was applied.

C. Treatment methods

Enzymatic treatment: 50 g of coconut rasp were mixed with 50 ml of water containing 1% (w/w) cellulase or mixture of cellulase and pectinase (technical grade enzyme from Novozyme, Switzerland) enzyme. After that the samples were incubated in a water bath at 50 °C for 6 h.

Thermal treatment: 50 g of coconut rasp was mixed with 50 g of distilled water and heated at 80 °C for 4h. Freeze thaw treatment: 50 g coconut rasp was packed in a HDPE bag and stored at -20 °C for 24 h. The sample was then thawed at room temperature and mixed with 50 g distilled water prior to pressing.

High electric field pulse treatment: 50 g of coconut rasp was placed in a High electric field pulse chamber (the electrode surface was 10X20 cm) and 50 ml tap water (conductivity=0.39 µS) was added. After that the sample was HELP treated at field strength of 4.29 kV/cm (capacity of capacitor=4µF) for 168 pulses.

Pressing: For pressing of samples a hydraulic press machine was applied. The pressing was conducted at 40 bars for 15 min.

Oil separation from coconut milk: coconut milk (about 2 liter) was stored in a refrigerator at +4 °C for 24 h. After that the cream phase of coconut milk was separated and subjected to oil separation experiments. The high electric field pulse treatment of coconut cream was conducted at 4kV/cm (at 4µF) and pulse nr. of 50, 100 and 150 pulses. The heat experiment for oil separation was carried out at 60 to 90 °C and 15 min. For ohmic heating (OH) treatment the coconut cream was placed in the same treatment chamber as the HELP treatment chamber but instead of High voltage a low voltage (26 Volt, AC current, 50 Hz) transformer was applied. The ohmic heating time was adjusted to achieve the desired temperature (60 to 80 °C) inside the treatment chamber. The HELP, OH or heat treated coconut cream was cooled to about 50 °C and centrifuged at this temperature for 15 min at 4000 rpm. The phase separation after centrifugation was determined and the % oil separation was calculated.

D. Analytical methods

Weight of juice during pressing was determined using the gravimetric method. The oil content in the coconut milk was measured using the Gerber method. The water content of coconut milk was determined using the oven drying method (at 105 °C, 4h).

Cell disintegration degree (Zp) was calculated using measurement of electrical conductivity of sample before and after treatment (Equation 1).

$$Zp = \frac{I_t - I_0}{I_f - I_0} \times 100 \qquad (1)$$

Where I_t is electrical conductivity of sample after treatment, I_o is electrical conductivity of untreated sample, and I_f is electrical conductivity of sample after freezing

III. Results and Discussion

A. Effect of thermal treatment on cell permeabilozation of coconut meat

Heat treatment of coconut meat at 80 °C led to thermal cell disintegration, however for an effective cell disintegration (Zp of 80 % and higher) treatment time of 15 min and longer was necessary (Figure 1).

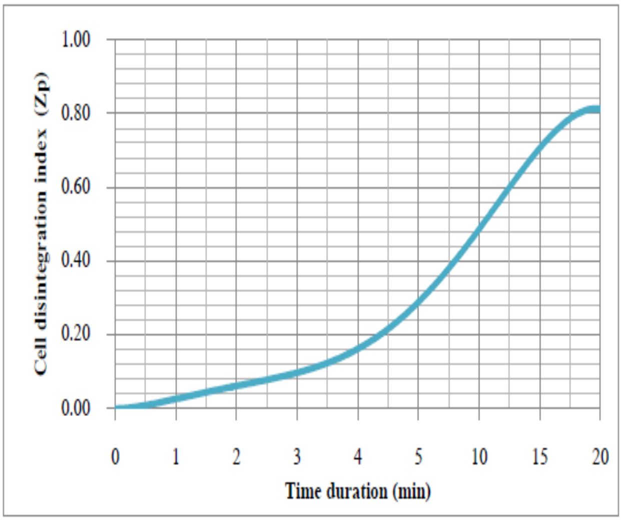

Fig.1. effect of thermal treatment at 90 °C on cell permeabilization of coconut meat

B. Effect of thermal treatment on cell permeabilozation of coconut meat

Increasing the pulse number from 5 to 60 pulses, a continuous increase in the cell permeabilization (Zp) of coconut meat at room temperature was observed (Figure 2). Further increasing pulse number up to 100 pulses led to only slight increasing of Zp. The cell permeabilization using HELP treatment was very fast (about 1 min for 60 pulses and pulse frequency of 1Hz) compared to thermal processing (≥15 min). The energy consumption for cell permeabilization using the HELP process (60 Pulses, 4 µF, 4.29 kV/cm) was distinctly lower (about 40 kJ/kg) compared to thermal cell permeabilization (at 90 °C about

240 kJ/kg). This indicated the advantages of HELP technique for cell permeabilization of plant foods.

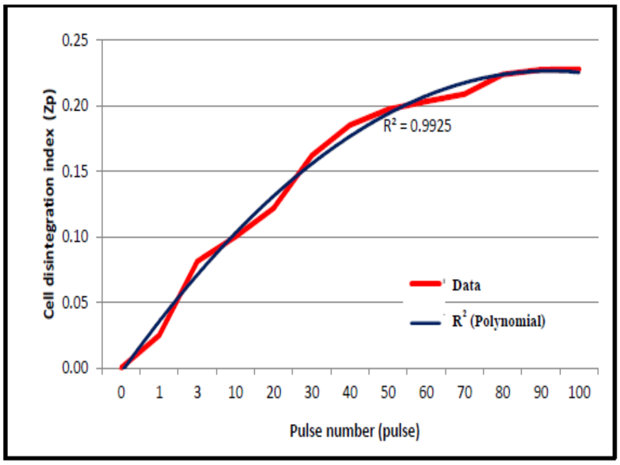

Fig.2. Effect of pulse number during HELP treatment on cell permeabilization of coconut meat

C. *Enzyme treatment of coconut meat*

Application of cellulase and pectinase enzyme showed a positive effect on coconut milk extraction. Whereas the remaining oil in pressed coconut rasp for untreated samples was more than 55 % (on the basis of dried pressed rasp), the oil content in pulp of with cellulase and mixed of cellulase and pecinase enzyme treated samples was distinctly lower (about 44.3 to 41.5 % respectively) (Figure 3). In addition, the enzyme treated samples showed lower water content in pressed coconut pulp compared to untreated samples (Figure 4).

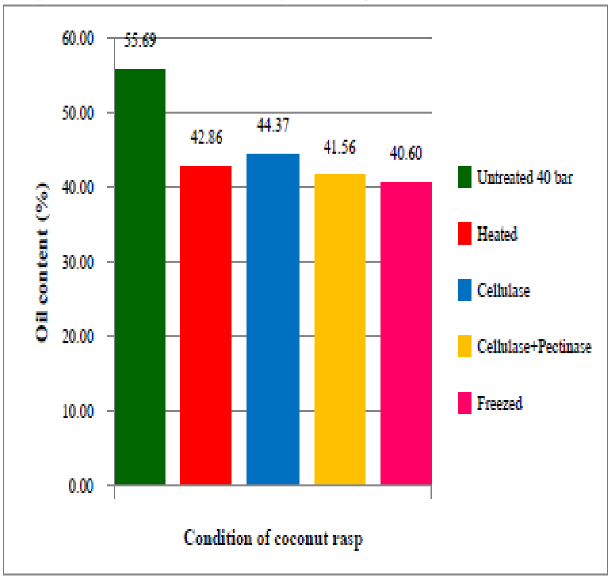

Fig.3. Effect of enzyme treatment of coconut rasp on remaining oil in pressed rasp

D. *Effect of high electric field pulse on oil content and total fat extraction from coconut meat*

Using HELP treatment at 4.29kV/cm field strength and 165 pulses it was possible to reduce the remaining oil in pressed pulp (Figure 5). The HELP pretreated coconut rasp showed distinctly lower (about 50 %) oil content after pressing compared to untreated pressed coconut rasp (54.5%) and comparable oil content with thermal and freeze thawed pressed coconut pulp. Furthermore, the remaining water in pressed pulp of HELP pretreated samples was distinctly lower compared to untreated samples and nearly similar to heat treated or freeze thawed pressed pulp (Figure 6).

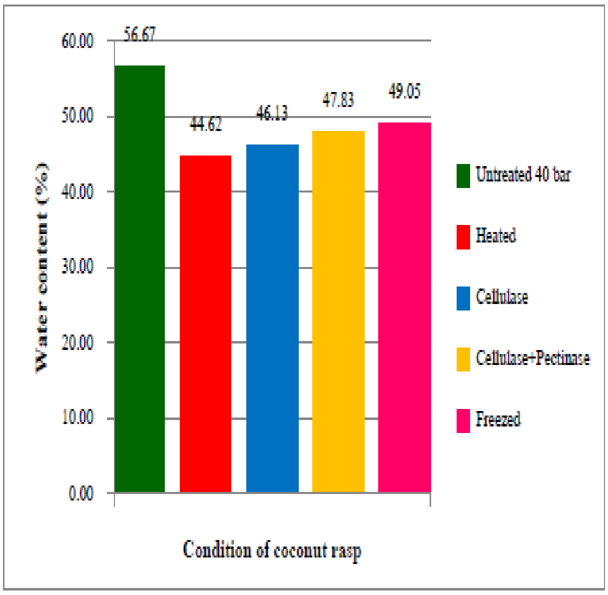

Fig.4. Effect of enzyme treatment on water content in coconut milk

Table 1: Effect of different pre-treatment methods on amount of coconut milk, pH and conductivity of coconut milk

Condition	Untreated	Thermal	HELP	Freeze-thaw
Weight of coconut milk (g)	74.03	78.14	79.68	82.20
Total fat extracted (g)	13.70	19.14	19.12	20.55
pH	3.88	3.93	3.86	5.64
Conductivity	6.48	6.87	6.47	6.34

In Table 1 the composition of coconut milk after different pretreatments is demonstrated. HELP treatment led to higher yield of coconut milk (79.67%) compared to untreated (74.03%) and was similar to thermal treated (78.14%) or freeze thawed samples (82.20%). The pH and electrical conductivity of extracted coconut milk using HELP technique was comparable with untreated coconut milk and slightly lower than thermally treated coconut milk.

Interestingly, the HELP pretreatment led to increased oil concentration (24 %) in extracted coconut milk compared to untreated samples (18.5 %) (Fig.7). Additionally, The HELP process is a fast (process duration less than 3 min) and energy saving method (less than 20kJ/kg compare to about 250 kJ/kg energy consumption for thermal processes at 90 °C).

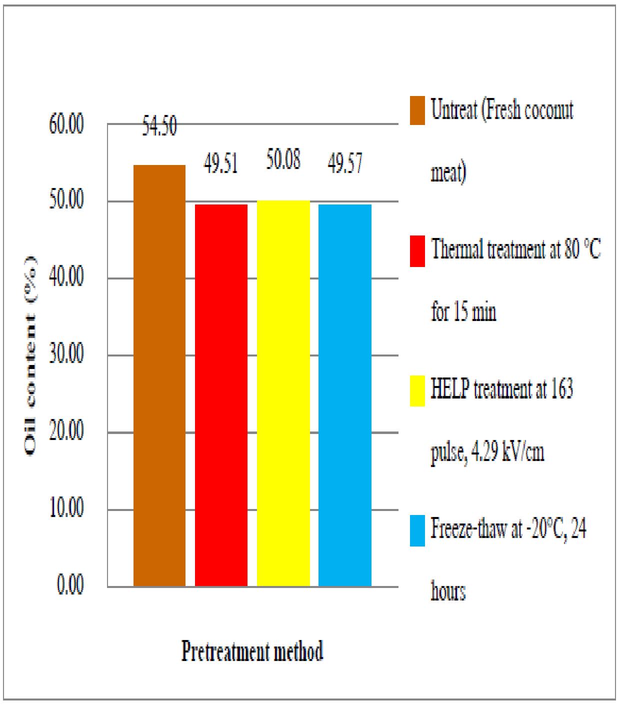

Fig.5. Effect of HELP treatment of coconut rasp on remaining oil in pressed rasp

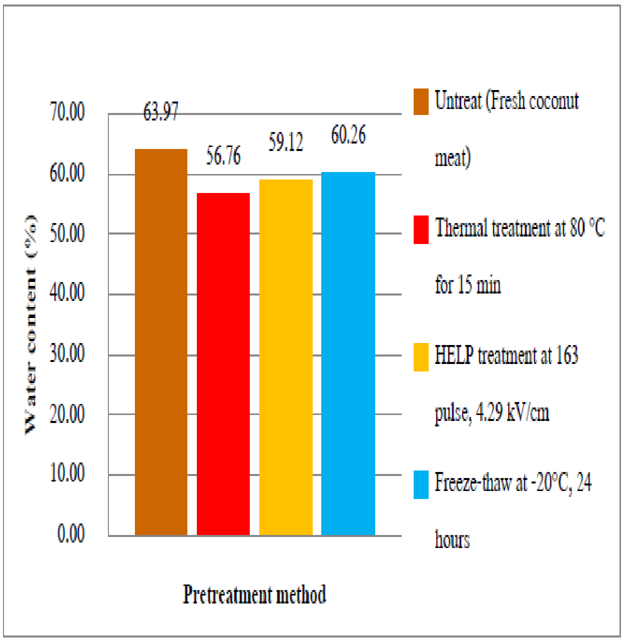

Fig.6. Effect of HELP treatment of coconut rasp on remaining water in pressed rasp

E. Oil separation from coconut cream using thermal process

Increasing the temperature during thermal oil separation from coconut cream increased the amount of separated oil during subsequent centrifugation (4000 rpm, 15 min). Adding salt (NaCl) at concentrations of 5 to 15 % w/w showed positive effect on oil separation at given temperature during thermal treatments (60 to 90 °C)(Figure 8). Increasing salt concentration in coconut cream increased the total oil separation of thermally treated coconut cream. Up to about 42 % oil separation was achieved after thermal treatment of coconut cream containing 15 % salt at 90 °C.

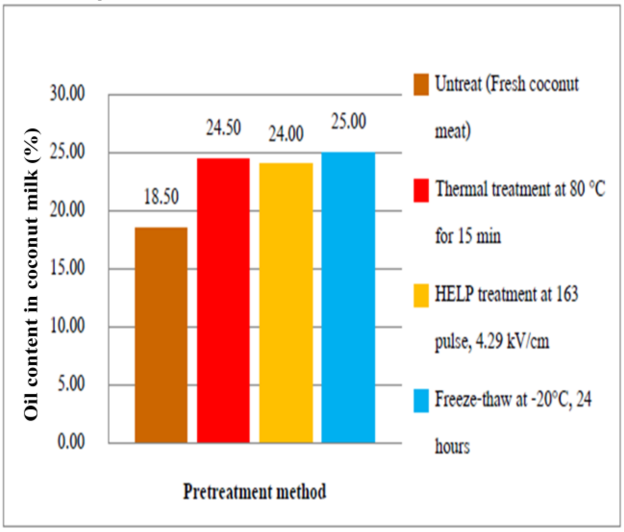

Fig.7. Effect of different treatment on oil content in coconut milk

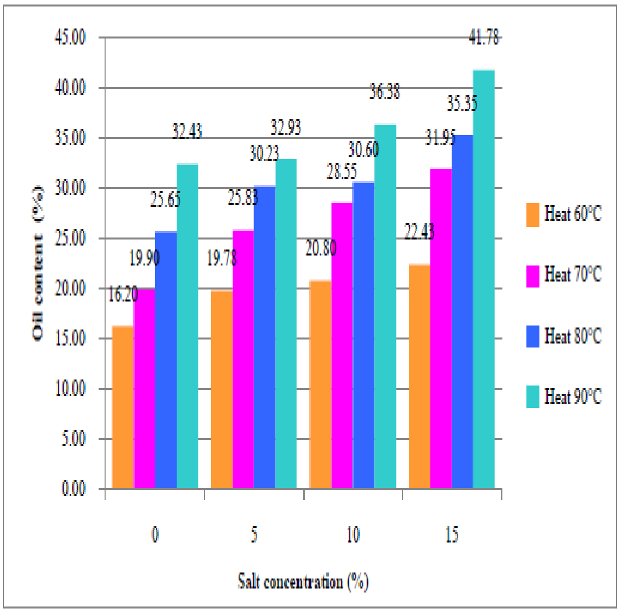

Fig.8. Effect of salt concentration of thermal oil separation from coconut cream

F. Oil separation from coconut cream using HELP, OH and thermal process

Surprisingly, using high electric field pulse technique at a moderate temperature (about 45 °C) it was possible to achieve oil separation from coconut cream similar to the thermal process (at 90 °C) at distinctly lower energy consumption and shorter process time. Using HELP treatment at 4kV/cm and 150 pulses (about 2.5 min process duration) with energy consumption of about 75 kJ/kg (temperature increase during process was about 15 °C) it was possible to achieve similar oil separation compared to thermal treatment at 90 °C. Comparison between the thermal treatment and ohmic heating (OH) process has shown that at the same energy consumption as the thermal process, higher oil separation could be achieved using ohmic heating, than only thermal treatment (Figure 7).

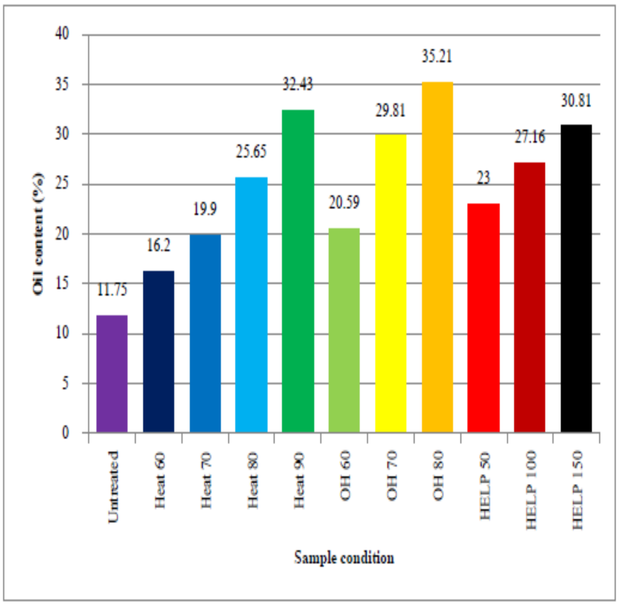

Fig.9. Effect of Ohmic heating and HELP treatment at different pulse number oil separation from coconut cream

IV. Conclusion

The measurement of cell disintegration degree after HELP treatment has clearly shown that the HELP treatment at room temperature could permeabilize the coconut meat in a very short time (less than 1 min) and distinctly lower energy consumption compared to thermal treatment. Interestingly the HELP pretreatment of coconut meat before pressing increased not only the milk yield (from 74% to 79%) but also increased the oil content in the pressed coconut milk.

Comparison between the effects of high electric field pulse and thermal treatment on coconut oil separation from coconut cream has indicated that high electric field pulses have the ability to separate coconut oil at considerably shorter pretreatment times (50 to 150 sec.) and lower energy consumption (less than 75 kJ/kg) compared to thermal treatment (15 min; 250 kJ/kg).

Adding salt to heat pretreated coconut cream affected the oil separation during centrifugation. Increasing the salt concentration from 0 to 15% increased the oil separation considerably.

Overall, using high electric field pulse as a new treatment method can help to increase the extraction of coconut oil from coconut meat and improve coconut oil separation from coconut cream as well. Also high electric field pulse as pretreatment required less treatment time compared to thermal treatment and freeze-thaw.

Acknowledgment

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