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COCOA BUTTER EXPRESSION FROM COCOA NIBS : EFFECTS OF PRE-TREATMENT AND PROCESS PARAMETERS ON EXPRESSION YIELD

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Abstract :

Cocoa butter is obtained in industrial conditions from cocoa liquor using hydraulic presses with an average oil yield of 42%. Our objective was to study the extraction of cocoa butter directly from cocoa nib and to determine the influence of pressing parameters such as the type of beans (green bean (GB), roasted alkalised bean (RAB), roasted bean (RB)), temperature, and pressure on cocoa butter yield. The extraction result depends on the rheological behaviour of the cake, which can be modelised with a four component Kelvin-Voigt model. The RAB (with a yield of 39%) is easier to press than the RB (38%) and GB (13%). The global mean compressibility coefficients of the Kelvin-Voigt model are 1.4, 1.7 and 2.1 MPa respectively for RAB, RB, and GB.

Key words : hydraulic expression, cocoa butter, compressibility modulus, rheological behaviour.

1. Introduction

Chocolate is a common consumption food made from cocoa butter, cocoa mass and other ingredients. Several technologies have been tested to produce different kinds of it. In 1828, the Danish Van Houtten manages to extract cocoa butter by pressing.

Since the beginning of the industrial production of chocolate, cocoa bean liquor (suspension of 10 μm particles in butter) must be produced to obtain cocoa butter [1]. An alternative process is investigated in this study. We want to obtain cocoa butter directly from cocoa nibs (broken deshelled cotyledons of cocoa beans).

Pre-treatments such as physics [2] (size reduction, cracking), thermal (pre-heating, drying), chemical (enzymes [3]) have permitted to increase the yield of oil from different seeds. We have investigated the incidence of chemical (alkalisation) and thermal (roasting) pre-treatments on the oil yield. Influences of pressure and temperature during the expression process have been also tested.

2. Materials and methods

2.1 Cocoa nibs

They are obtained by crushing of whole beans and the particles have sizes up to 5 mm (figure 1). Three types of bean were used : Roasted only Bean (RB), Roasted Alkalised Bean (RAB) and no treated beans (Green Bean (GB)).

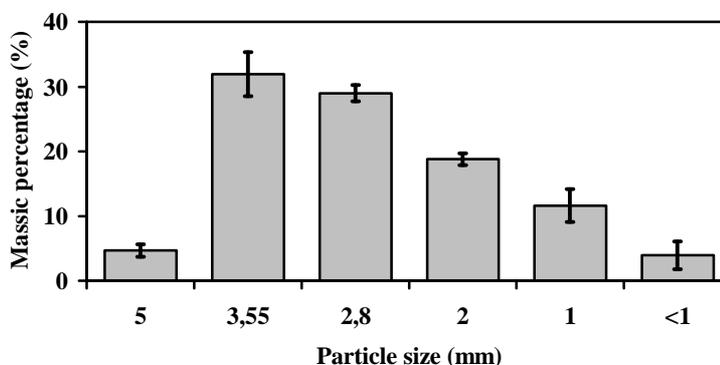


Fig. 1 : Size distribution of five samples of RAB.
Vertical bars represent standard deviation

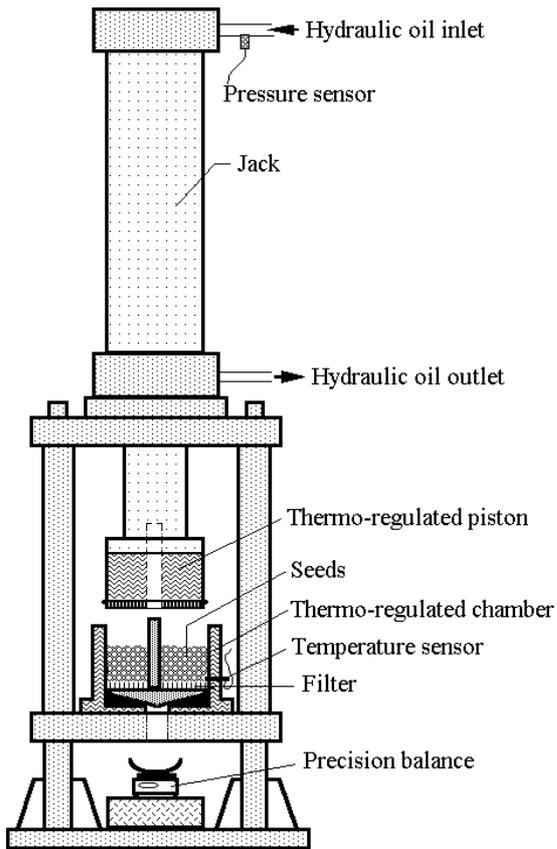


Fig. 2 : Hydraulic press.

2.2 Hydraulic press

The hydraulic press we used (figure 2) provides a maximum pressure of 13 MPa and is built around a chamber where 0.400 kg of seeds can be placed. An internal 140 mm diameter jack generates pressure that is measured with a sensor (Kulite-JPB, type C610RA, Bois d'Arcy, France) placed in the hydraulic oil inlet. Both piston and chamber are thermo-regulated (30 to $130^{\circ}\text{C} \pm 2^{\circ}\text{C}$) using thermal oil heating with a boiler (Parmilleux type H10, Lyon, France). Expressed oil is continuously measured with a centigram precision balance (Mettler-Toledo type PM6000, Viroflay, France). Output signals (jack pressure, chamber pressure, expressed oil mass) are recorded and computerised at a frequency of one hertz.

2.3 Rheological model

A typical experimental curve is shown on figure 3. The cake consolidation phase starts with the maximum outflow.

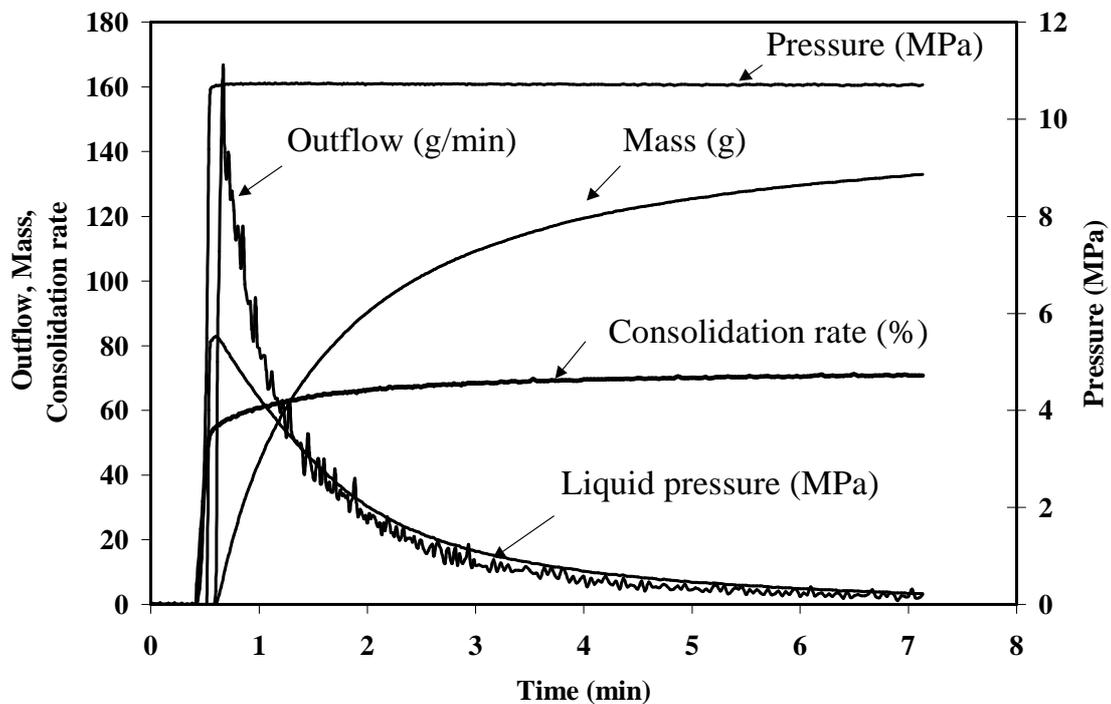


Fig. 3 : Experimental curve of 0.400 kg of RAB pressed at 10 MPa and 90°C

The consolidation rate U is calculated from the volume V of oil extracted at time t divided by the volume at infinity V_∞ , which is the maximum theoretical volume of extractable oil at an infinite time :

$$U = \frac{V}{V_\infty}, \text{ with } V_\infty = \frac{P_p Ah}{2G} \quad (1)$$

where G is the cake compressibility modulus (Pa) ; P_p the applied pressure by the piston (Pa) ; h the cake initial height (m) and A the filter surface (m²).

The improvement of expression efficiency is obtained by the rise of pressure and the decrease of G , which corresponds to an increase of the cake porosity.

U is represented with a four exponential model [4].

$$U = \frac{V}{V_\infty} = \left[\frac{1}{\frac{1}{G_{1_0}} + \frac{1}{G_1} + \frac{1}{G_2} + \frac{1}{G_3}} \right] \left[\frac{1}{G_{1_0}} (1 - e^{-v_0 t}) + \frac{1}{G_1} (1 - e^{-v_1 t}) + \frac{1}{G_2} (1 - e^{-v_2 t}) + \frac{1}{G_3} (1 - e^{-v_3 t}) \right] \quad (2)$$

2.4 Experimental design

There are 3 types of beans : RAB, RB and GB. 3 levels of pressure (9, 10 and 11 MPa) and 2 levels of temperature (90 and 100°C) were studied.

A complete factorial design was chosen for this study. The experiments were repeated two times.

The response tested was the *oil yield* defined as : $\frac{\text{extracted oil mass}}{\text{initial product mass}}$.

The yield at infinity is defined as the oil mass that would be extracted during an infinite time in the consolidation phase.

3. Results and discussion

The results of the experimental design are shown on table 1.

Source of variation	Sum of square	Degree of freedom	Experimental Fischer	$F_{1-0.5}$	P value
Type of beans (3 types)	80064	2	331	3.44	0.000
Pressure (3 levels)	387	2	1.60	3.44	0.224
Temperature (2 levels)	157	1	1.30	4.30	0.266
Interaction Temperature-Pressure	36.6	2	0.15	3.44	0.860
Interaction Bean-Pressure	734	4	1.52	2.82	0.232
Interaction Bean-Temperature	741	2	3.07	3.44	0.067
Residual	2660	22			
Total	84782	35			

Tab. 1 : ANOVA results (RAB - RB - GB). When $P \text{ value} < 0.01$, then the factor is highly significant. When $0.01 < P \text{ value} < 0.05$, then the factor is significant.

3.1 Effect of bean type

The ANOVA shows that the type of beans is the only significant factor. The GB yield (figure 4) is very low (from 4.8 to 17.7% depending on the other factors) compared with the two others (from 32.9 to 42.6%). Thus the pressability of GB is considered as very poor and the variance analysis has been recalculated without GB results (table 2).

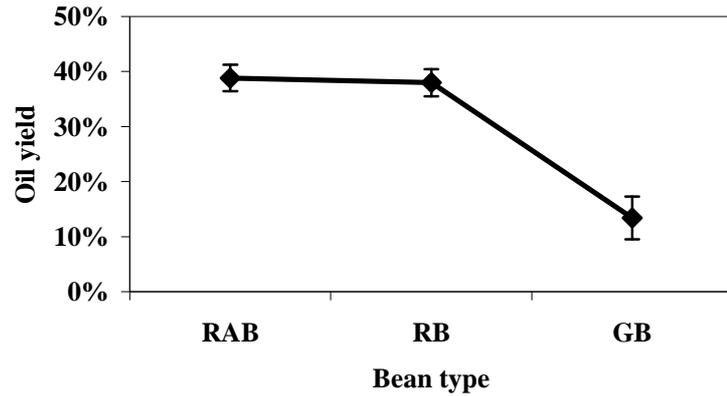


Fig. 4 : Effect of bean type on the oil yield

3.2 Limitation to RAB and RB types

3.2.1 Oil yields

	Source of Variation	Sum of square	Degree of freedom	Experimental Fischer	$F_{1-0.5}$	P value
Yield	Type of beans (2 levels)	69.2	1	0.89	4.60	0.360
	Pressure (3 levels)	108	2	0.70	3.74	0.513
	Temperature (2 levels)	674	1	8.72	4.60	0.010
	Interaction Temperature-Pressure	163	2	1.06	3.74	0.373
	Interaction Bean-Pressure	48.1	2	0.31	3.74	0.738
	Interaction Bean-Temperature	0.02	1	0.00	4.60	0.987
	Residual	1082	14			
	Total	2145	23			
Yield at infinity	Type of beans (2 levels)	312	1	4.97	4.60	0.043
	Pressure (3 levels)	40.2	2	0.32	3.74	0.732
	Temperature (2 levels)	486	1	7.74	4.60	0.015
	Interaction Temperature-Pressure	118	2	0.94	3.74	0.413
	Interaction Bean-Pressure	5.87	2	0.05	3.74	0.954
	Interaction Bean-Temperature	10.1	1	0.16	4.60	0.694
	Residual	879	14			
	Total	1853	23			

Tab. 2 : ANOVA of extracted mass and mass at infinity (RAB – RB)

According to the ANOVA (table 2), the temperature has a significant effect : its rise from 90 to 100°C increases the oil yield from 37% to 39.7% and the yield at infinity from 33.9% to 36.15% (figure 5).

The type of beans has only a significant effect on the yield at infinity (figure 6). This means that the beans have a difference of compartment, which does not appear during the first hour of

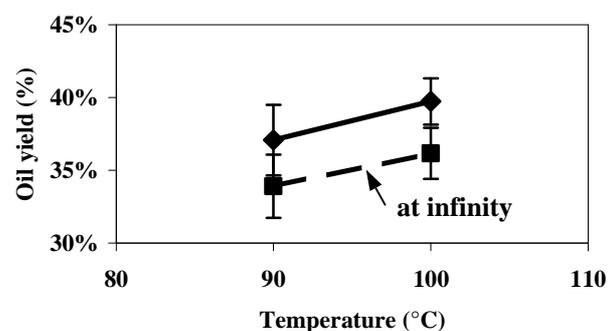


Fig. 5 : Effect of temperature on extraction yields

pressing. Globally the RAB is easier to press than the RB. The existence of different phases of pressing explains it. Before the consolidation phase a phenomenon cancels this difference : RB is more compressible at the beginning of expression and RB lipids are more fit for expression than RAB lipids. This hypothesis is supported by the maximum flow obtained at the end of the first two phases (RAB : 1.8 g/min and RB : 2.5 g/min).

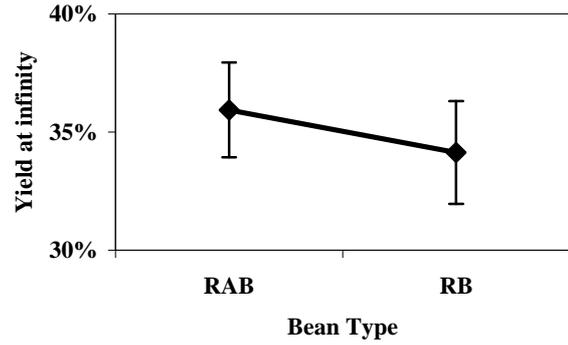


Fig. 6 : Effect of bean type on yield at infinity

3.2.2 Compressibility modulus

The compressibility modulus estimates the difficulty for compressing a volume. Its increase means that, for a same applied constraint, the deformation decrease. No significant factors were found for G_{10} and G_1 .

	Source of Variation	Sum of square	Degree of freedom	Experimental Fischer	$F_{1-0.5}$	P value
G_2	Type of beans (2 levels)	4216	1	14.23	4.60	0.002
	Pressure (3 levels)	1505	2	2.54	3.74	0.115
	Temperature (2 levels)	5.61	1	0.02	4.60	0.893
	Interaction Temperature-Pressure	920	2	1.55	3.74	0.256
	Interaction Bean-Pressure	4.05	2	0.01	3.74	0.993
	Interaction Bean-Temperature	242	1	0.82	4.60	0.381
	Residual	4148	14			
	Total	11042	23			
G_3	Type of beans (2 levels)	2283	1	16.62	4.60	0.001
	Pressure (3 levels)	481	2	1.75	3.74	0.210
	Temperature (2 levels)	5.80	1	0.04	4.60	0.840
	Interaction Temperature-Pressure	122	2	0.44	3.74	0.651
	Interaction Bean-Pressure	88.0	2	0.32	3.74	0.731
	Interaction Bean-Temperature	246	1	1.79	4.60	0.202
	Residual	1924	14			
	Total	5149	23			
G_{global}	Type of beans (2 levels)	50.2	1	7.88	4.60	0.014
	Pressure (3 levels)	75.6	2	5.93	3.74	0.013
	Temperature (2 levels)	1.98	1	0.31	4.60	0.310
	Interaction Temperature-Pressure	4.43	2	0.35	3.74	0.712
	Interaction Bean-Pressure	4.22	2	0.33	3.74	0.724
	Interaction Bean-Temperature	6.32	1	0.99	4.60	0.336
	Residual	89.3	14			
	Total	232	23			

Tab. 3 : ANOVA of compressibility modulus (RAB – RB)

The bean type is the only factor which explains the variations of G_2 and G_3 : it is a highly significant factor (table 3). This factor is also significant for G_{global} . It has the same effect on the three compressibility modulus (figure 7). RAB presents a better pressability than RB during the phase of deformation and the extra-cellular volume liquid exit. The alkalisation modifies the material structure and makes it more adapted for pressing. As alkalisation is obtained at 150°C in an alkaline solution, modifications should happen on the cellular wall.

The global compressibility modulus mean $\left(\frac{1}{G} = \frac{1}{G_{10}} + \frac{1}{G_1} + \frac{1}{G_2} + \frac{1}{G_3}\right)$ is 1.39 MPa for RAB and 1.68 MPa for RB.

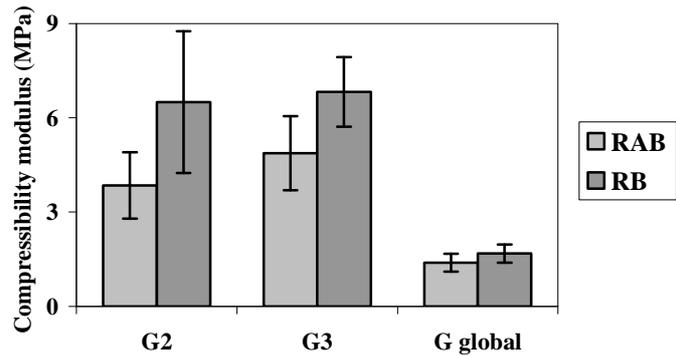


Fig. 7 : Effect of bean type on compressibility modulus

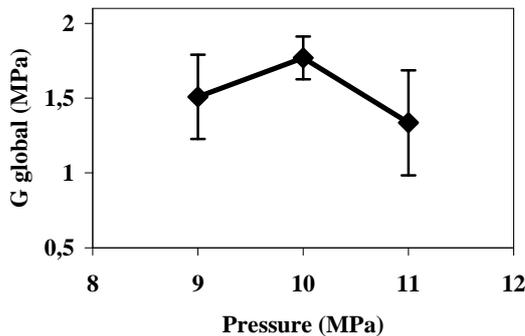


Fig. 8 : Effect of pressure on G global

The pressure has a significant effect on the G global (figure 8). Its increase from 9 to 10 MPa has a negative effect on the pressability : cake drainage is not facilitated. But a pressure increase up to 11 MPa has a positive effect on the pressability : the cake structure has been modified and drainage is improved.

4. Conclusion

The cellular liquid expression is complex and influenced by bean characteristics and pressing conditions. Our model well describes cocoa nibs comportment during the consolidation phase. The absence of thermal and chemical pre-treatment reduces dramatically the oil yield. Far from industrial pressure (70-80 MPa), the temperature is the most influent factor on RB and RAB oil yields in the tested range of pressure (9-11 MPa). The bean type has a significant effect on yield at infinity : there is a difference of comportment that appears for long time pressing. Roasting and alkalisation give better results than single roasting. The same difference is also found in the compressibility modulus. The pressure has only an effect on the global compressibility modulus.

This study shows clearly that the comportment of cocoa nibs and oilseeds are similar. Continuous process is then a possible option.

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