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THE TEMPERING QUALITY EVALUATION OF COCOA LIQUOR DURING INDUSTRIAL PRODUCTION.

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ABSTRACT

The tempering quality evaluation of the crude cocoa liquor with average fat content 55.0 ± 0.3 % and an average acid value, 1.57 ± 0.34) has been established. The various parameters considered were recasting time (RT) and appearance (AP) of the tempered product on one hand and the flow (F) of the crude liquor on other hand. It has been established that average performance of the tempering can be described satisfactorily with a linear model. This can allow to estimate easily the quality of the tempered product by the measurement of the angle θ of the tempering curve. It has been shown that when θ and F correspond respectively to [20° – 30°] and [1600 – 1800] kg/h, the tempering quality was good. The tool installed is useful for a quality control within an industrial production since its application allows to solve to 98%, the problem of the product poor quality.

KEY WORDS: Industrial tempering, tempering curve, cocoa liquor, cocoa beans

INTRODUCTION

The tempering of Cocoa liquor is an operation that consists in a slow cooling in order to confer a firm consistence to it. During this cooling, some α crystals essentially appear and are progressively transformed into β and β' crystals around 20 °C. The β form is eliminated by increasing the temperature to 29°C (Grizzle et al., 1969). Most of the authors took interest in either the tempering of Chocolate, which contains sugar, flavouring compounds and lecithin or the tempering of pure cocoa butter. (Jackson 1999; Wilson et al., 1963 and Foubert et al., 2002). The work related to the tempering of the crude liquor obtained after crushing of broad beans have not been reported. This operation is however significant since the product intended for export is transported more easily. Thus, because of the great fluctuation of the composition of cocoa broad beans according to their origin and their storage conditions [Lobas 1997 and Claiserian et al., 1989], the process of tempering is sometime badly controlled during the production in the industrial process. This fact is partly responsible of the poor quality of the product. So, how to determine tempering quality criteria easily usable by workers to assess the quality of the tempered product during the production. This study proposes an empirical model that takes into consideration the various parameters such as cocoa liquor flow (F) recasting time (RT) and appearance (AP) of the tempered product. The recasting time is one of the fundamental criteria for the customers since the tempered product must be molten for further utilization. It is thus important for this time to be the lower as possible. As for appearance it allows to the customers to assess visually the quality of the tempered product.

The change of the temperature as a function of the time during the tempering leads to three types of curve. For instance, figure 1 shows a general curve of a chocolate with fat content between 26 and 35% (Lyman, 1992). In theses figure, [AB] represents the first linear cooling phase, [BC] the crystallization phase and [CD] the second linear cooling phase.

EXPERIMENTAL DETAILS AND CALCULATION

The tempering was carried out in an industrial cooler apparatus (an exchanger) Aasted Microverk 3000 P, with four successive stages.

U_1: stage of primarily cooling
U_2: stage of cooling
U_3: stage of crystallization
U_4: stage of reheating

The liquor introduced into the first compartment passes successively in the compartment 2, 3 and 4, with a constant flow. A sample (a bloc of 20 kg) of the obtained product was heated at 100°C in a oven, and the recasting time (RT) was obtained when the entire sample was completely melted. The sample was considered to be:

- very good when RT was lower than 30 minutes,
- good when RT lay between 30 and 40 minutes,
- bad when RT was beyond 40 minutes.

The appearance was visually appreciated by a team of six peoples especially formed for this task and referred to the colour, texture and hardness of the sample. It was considered to be:

- very good when the product was chocolate, with a good consistency and texture,
- good for a product without one of these qualities,
- bad for a product with none of these qualities.

Three intervals of flow were chosen: ([1600 – 1800] kg/h,

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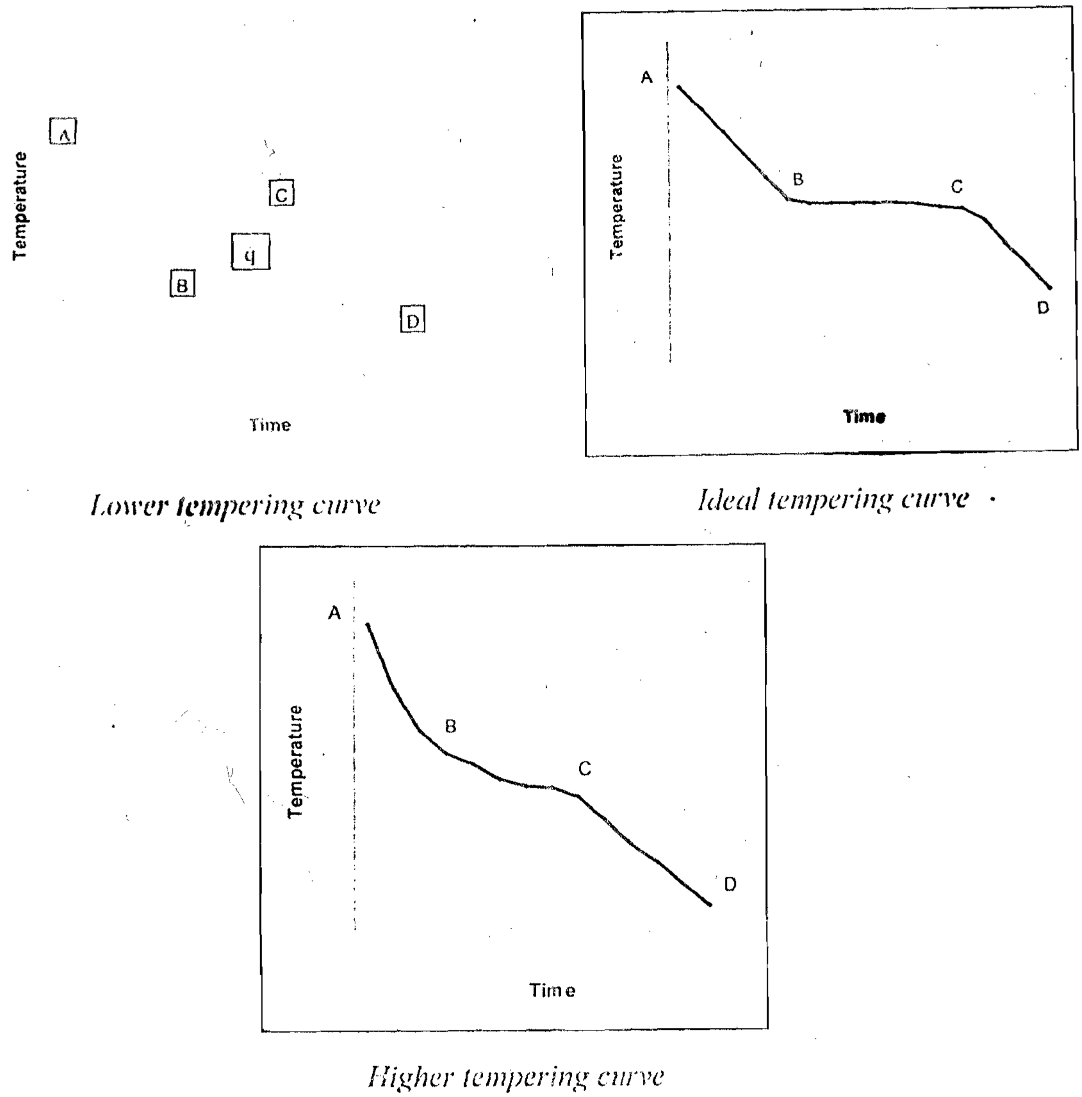

Fig. 1. A qualitative presentation of possible tempering curves

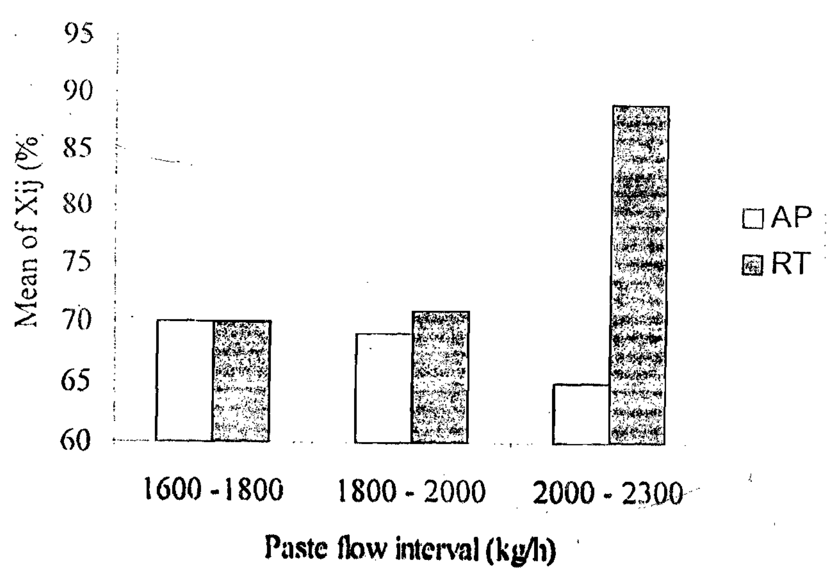

Fig. 2: Respected standard percentage means for criterion **RT** and **AP** as a function of liquor flow interval.

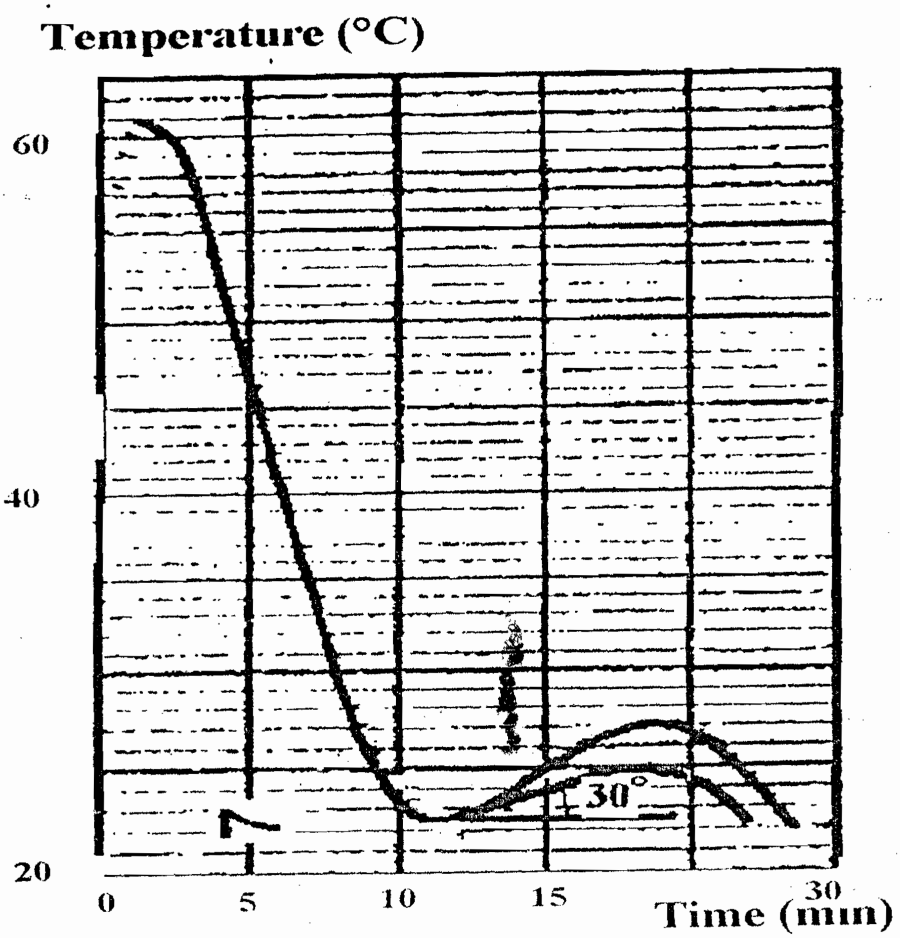

Fig. 3: Tempering curve of cocoa liquor with about 55% of fat materials

Table 1: Results of sampling

		% of very good samples		% of good samples		% of bad samples	
Interval Class	Liquor Flow (kg/h)	RT	AP	RT	AP	RT	AP
[0° – 10°]	[1600 – 1800]	71.43	57.14	28.57	42.86	0.00	0.00
	[1800 – 2000]	86.67	80.00	13.33	20.00	0.00	0.00
	[2000 – 2300]	75.00	100.00	15.00	0.00	0.00	0.00
[10° – 20°]	[1600 – 1800]	62.50	50.00	37.50	12.50	0.00	37.50
	[1800 – 2000]	80.00	90.00	20.00	10.00	0.00	0.00
	[2000 – 2300]	100.00	50.00	0.00	50.00	0.00	0.00
[20° – 30°]	[1600 – 1800]	70.00	70.00	30.00	30.00	0.00	0.00
	[1800 – 2000]	50.00	100.00	0.00	0.00	50.00	0.00
	[2000 – 2300]	100.00	0.00	0.00	75.00	0.00	25.00
[30° – 40°]	[1600 – 1800]	83.34	100.00	16.66	0.00	0.00	0.00
	[1800 – 2000]	71.43	42.86	28.57	57.14	0.00	0.00
	[2000 – 2300]	83.33	91.67	16.67	8.33	0.00	0.00
[40° – 50°]	[1600 – 1800]	75.00	75.00	25.00	25.00	0.00	0.00
	[1800 – 2000]	66.67	33.33	33.33	66.33	0.00	0.00
	[2000 – 2300]	88.89	11.11	11.11	88.89	0.00	0.00

RT: Recasting time

AP: Appearance

Table 2: Results of the model

Response $Y_{[a-b]}$	$Y_{[0°-10°]}$	$Y_{[10°-20°]}$	$Y_{[20°-30°]}$	$Y_{[30°-40°]}$	$Y_{[40°-50°]}$
[1600 – 1800] kg/h	514.28	400.00	510.00	566.65	525.00
[1800 – 2000] kg/h	553.34	550.00	200.00	485.72	466.33
[2000 – 2300] kg/h	530.00	550.00	450.00	476.33	488.89

Local optimum in bold font and global optimum in underline bold font

[1800 – 2000]kg/h, [2000 – 2300] kg/h). These intervals represented the flows usable for the customers high or weak demand.

The tempering curves were obtained directly owing an integrated apparatus that plot the evolution of the liquor temperature as a function of the time. The angle θ was then obtained from the change of curve as shown in figure 1. Assuming that we want to have 5 subintervals (Foubert et al., 2002), if the angle field varies between 0 and 50°, then the class interval width is 10.

The experimental procedure consisted in varying the flow of the liquor in the tempering apparatus and plotted the tempering curves. A sample of the product obtained was taken and RT and AP were performed. This operation is repeated 15 times for each interval of flow F and an examination of the results was carried out according to criteria previously stated.

Explanation of the results has been done using a first order equation (N'dri, 1994 and Pontillon, 1998) that represented the objective function.

$$Max\ Y_{[a-b]} = \Sigma\Sigma\alpha_i\beta_j X_{ij} \quad (3)$$

$$1 \leq i \leq 3 \text{ and } 1 \leq j \leq 2$$

Where X_{ij} represented % of sample respecting the level i of qualification of the criterion j,

α_i and β_j, the weights respectively of qualification levels i and parameter j. Arbitrarily,

$\alpha_1 = +2$ for very good sample, $\alpha_2 = +1$ for good ones and $\alpha_3 = -1$ for bad ones.

Assuming that the most important criterion was the recasting time of the product, a arbitrary weight $\beta_1 = 2$ was used for RT, and $\beta_2 = 1$ for appearance AP.

RESULTS AND DISCUSSION

The results are presented in Table 1 and table 2. It appeared in Table 2 that the Y values vary from 200.00 (when the angle was in the [20° – 30°] range and the flow rate was set to [1800 – 2000] kg/h) to 566.65 (at [30° – 40°] and [1600 – 1800] experimental conditions). In addition, it can be observed that, whatever the angle class interval, no specific order can be drawn according the flow rate. For instance, when the angle class interval is [0° – 10°], the smallest value of the response Y is obtained when the liquor flow rate corresponds to [1600 – 1800] kg/h range. Nevertheless, when considering the [20° – 30°] angle class interval, the smallest value of Y is reached at [1800 – 2000] flow rate interval. By considering the value of the objective function Y, if the flow F varied in interval [1600 – 1800] then the tempering is better if the curve presents an angle in interval [30° – 40°]. If the flow F is set in interval [1800 – 2000]kg/h then the tempering is better if the curve presents an angle in interval [0° – 10°]. If the flow F varied in interval [2000 – 2300] then the tempering is better if the curve presents an angle in interval [10° – 20°]. Finally according to table 2 the best tempering was obtained in the interval [30° – 40°] with a cocoa liquor flow between 1600 and 1800 kg/h. At these experimental conditions, it was observed that 84 % of samples respected recasting time standard and 100% respected the appearance one.

Moreover, the effect of the cocoa liquor flow on the tempering was studied. The results obtained are presented in figure 2, respectively for recasting time and appearance criteria. It appeared that the mean percentage of samples respecting the RT standard increases with the flow rate, while it decreases, when considering the AP criterion. Finally the ideal tempering curve was given by figure 3. The obtained model can be used as a predicted model to assess the tempering quality in regard of the criteria RT and AP.

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