Acta Agrophisica, 2002, 77, 51-60

ROASTING CONDITIONS AND COCOA BEAN QUALITY

W. Krysiak

Institute of Chemical Technology of Food, Technical University of Łódź
ul. Stefanowskiego 4/10, 90-924 Łódź, e-mail: krysia@snack.p.lodz..pl

Summary. Cocoa bean of Ivory Coast variety was roasted in the air at the temperature 110, 135 and 150°C, flow velocity v = 1.0 m/s and relative humidity 0.8-0.4, 2 and 5%. During thermal processing moisture content as well as total and volatile acidity were determined in the cocoa bean. On the basis of the obtained results it was found that roasting carried out for the whole time in the air at increased relative humidity (φ = 2 or 5%) contributed to the reduction of total and volatile acidity to much lesser extent than in the case when dry air (0.8-0.4) was applied.

Keywords: cocoa bean, roasting, total and volatile acidity, quality.

INTRODUCTION

Cocoa bean is the basic raw material for production of chocolate and chocolate products. One of the most important processes involved in cocoa bean processing is roasting. Very important for the final quality of a chocolate product is to select proper process parameters so as to obtain good physicochemical properties, e.g. desirable aroma, taste, colour or low enough acidity. In the research on convection roasting of cocoa bean carried out so far attention was focussed on the final physicochemical properties of the roasted bean [1,3,7,8,16]. However, it seems to be very important to learn how these changes proceed during the process.

There are numerous possibilities of thermal processing of cocoa bean. This is a result of introducing new design solutions of roasters [14, 15]. For a long time it was considered that the convection method had limited possibilities. This opinion changed when air circulation was introduced. Application of this solution enables air humidity control and consequently we can have an influence on the process of roasting and the quality of roasted bean.

One of significant indicators of cocoa bean roasting is acidity. Roasting contributes to the reduction of bean acidity. The final value of roasted bean acidity depends on its variety, the process of fermentation and on the roasting conditions. In the literature [1,2,7] the effect of temperature and time on roasted bean acidity has been well described, however, no studies have been published on the effect of relative air humidity on the value of this quality coefficient. It seems that it is important to know this dependence because of a possibility of using air recirculation in the process of roasting.

MATERIALS AND METHODS

Analysis of cocoa bean

The experimental material was cocoa bean of Ivory Coast variety. After quality assessment, raw bean was sorted and the fraction which contained medium size beans was used for studies. Unification of bean size ensured uniform roasting.

The beans from selected fraction were also subjected to physicochemical analysis using the methods which were usually applied for such a raw material. The whole bean, as well as the kernel were analysed from the point of view of moisture content [12], total acidity [11], volatile acidity [13], cocoa butter content [10], water-soluble tannin content [13] and the content of mineral substances (ash) [9].

A detailed description of analytical determinations was presented earlier [4,7, 8] in the studies discussing thermal processing of cocoa bean and in relevant standards.

Roasting of cocoa bean

Cocoa bean was roasted in a tunnel for thermal processing of vegetable materials.

Investigations were carried out using the following process parameters:

- air temperature 110, 135 and 150°C,
- relative air humidity of the order of 0.8-0.4, 2 and 5%,
- air flow velocity v = 1.0 m/s.

The air of relative humidity $\varphi = 2$ and 5% was obtained by introducing steam vapour to the stream of air heated to an adequate temperature. The experiments were confined to these two relative air humidities because the higher values of this parameter were not recommended for economic and microbiological reasons. For dry air the relative humidity ranged from 0.8 to 0.4% and depended on the air temperature.

To determine changes in quality parameters of cocoa bean not only after completing the process but also during roasting, each time when roasting conditions were settled down in the chamber, new portions of the bean of the weight about 200 g were placed on the scale pan by batching from funnels. This method of material batching ensured its uniform distribution in a single layer. In time intervals set for a given roasting method, e.g. every 15, 20, 30 minutes, and so on, roasted bean samples were taken and after cooling and deshelling were analysed to determine moisture content and total and volatile acidity. The time of thermal processing for particular roasting methods depended on reaching about 2% moisture content in the roasted cocoa bean.

As components analysed in the raw bean were changing during storage, all results were presented in diagrams in the form of reduced values obtained by dividing the actual value by its initial value.

Every roasting method and determination of selected quality coefficients were made in three parallel repetitions. Results including average values are given in this study.

RESULTS AND DISCUSSION

Table 1 gives analytical results for raw cocoa bean both sorted and not sorted. It follows from these data that the tested raw bean was characterised by quite good quality. This is confirmed by not too high total and volatile acidity and a relatively high content of cocoa butter. The bean contained 5.50% moisture on average. Other assessed quality coefficients of the bean such as colour, flavour, aroma, the number of correctly shaped beans, of mouldy and fermenting beans also revealed good quality of the raw material. In sorted bean the content of moisture, ash and cocoa butter, as well as total acidity were slightly higher (Tab. 1).

Table 1. Analysis of selected raw cocoa bean components

	Moisture content [%]	Total acidity [°n]	Volatile acidity [% acetic acid/d.m.]	Ash content [%]	Content of water-soluble tannins [%/d.m.]	Cocoa butter content [%/d.m.]
Whole non-sorted bean	5.50	13.44	0.12	3.45	-	53.65
Bean from fractions after sorting						
Whole bean	5.68	13.68	0.11	3.71	-	54.28
Kernel	4.85	14.58	0.12	3.03	10.0	59.43
Shell	11.72	-	-	9.01	-	3.17

Table 2 gives a comparison of time periods which are necessary for the bean to reach the required 2% moisture content as a result of roasting.

Table 2. Parameters of thermal processing of cocoa bean

Bean roasting temperature [°C]	Dry air φ = (0.8-0.4%)		Humid air φ = 2%		Humid air φ = 5%	
	Roasting time [min.]	Moisture content in bean [%]	Roasting time [min.]	Moisture content in bean [%]	Roasting time [min.]	Moisture content in bean [%]
110	70	2.08	90	2.11	100	1.94
135	35	1.89	45	2.09	60	1.97
150	30	1.92	30	1.96	45	1.97

Total acidity

Figures 1, 2 and 3 show changes in total acidity which occur in the cocoa bean roasted in changing air conditions. Figure 1 illustrates changes in total acidity of the bean roasted at the constant temperature T = 110°C and at air flow velocity v = 1.0 m/s, with variable relative air humidity reaching about 0.8, 2 and 5%, respectively. From curves shown in Fig. 1 it follows that taking into account the final values of total acidity, most advantageous is bean roasting in dry air (φ = 0.55%). After 70 minutes of the process at 2.08% moisture content in the bean, its total acidity was 12.82°n/d.m. which meant over 12% loss of this quality coefficient. The obtained data conform with the values quoted by Nebesny and Rutkowski [7] and Jinap [2,3]. When observing and comparing the curves representing changes in total acidity for relative humidity φ = 0.8% with 2 and 5% humidity, significant difference can be found. For dry air, in the whole roasting process a constant decrease of total acidity is observed. When air of 2 and 5% humidity is used for thermal processing of cocoa bean, only in the initial period, i.e. ca. 20 minutes of roasting, a significant decrease of total acidity occurs, then further roasting to 2% moisture content in the bean does not cause a visible decrease of this quality coefficient. This character of changes in the roasted bean can be explained by a so-called "balloon effect". It is manifested by the formation of a free space between the kernel and shell. The use of air with increased humidity contributes to this effect. Moisture present in the air in the initial period of roasting loosens the shell structure and enables heat transfer to the kernel, and next by diffusion with water vapour enables a quick removal of acidic substances contained in it. Therefore, in Figure 1 a distinct decrease of this quality coefficient is observed in the time up to 20 minutes as compared to roasting in dry air. After reaching this time the transfer is hampered because of the free space formation, but also because of smaller pressure of vapour removed from the kernel as compared to the pressure of vapour contained in the air which was heating the bean. Hence, no further decrease of total acidity is observed. The higher relative air humidity applied in the roasting, the lesser amount of acidic substances was removed from the cocoa bean. For the air with relative humidity equal to 2%, the total loss of the total acidity was about 7%, while the process carried out in the air with relative humidity 5% caused that acidity decreased by only 3.5%. In the case of bean roasting in the air of relative humidity $\varphi = 0.8\%$ no "balloon effect" is observed, and gradual changes of total acidity during the whole process are a result of temperature and slow moisture evaporation from the material along with acidic substances.

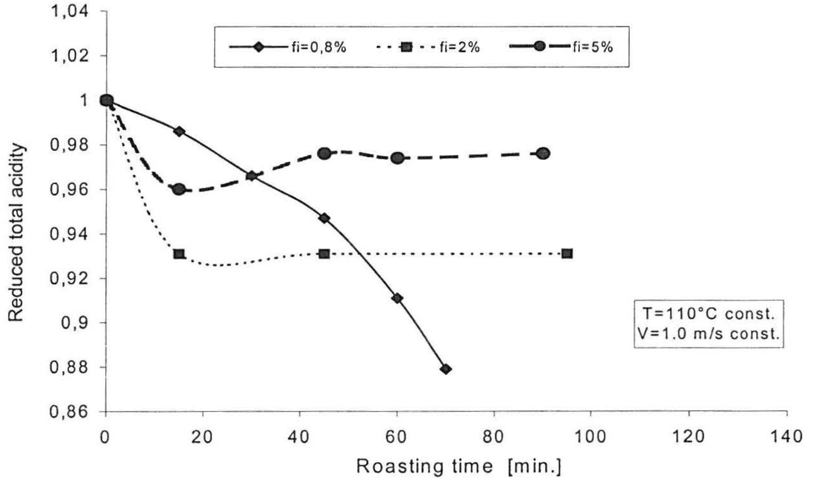

Fig. 1. Changes of total acidity in cocoa bean depending on applied roasting conditions.

The case is opposite when cocoa bean is roasted at the temperature 135°C (Fig. 2). In the process performed in the dry air ($\varphi = 0.55\%$), quick changes of bean total acidity are observed. This is particularly distinct in the time up to 15 minutes when this quality coefficient decreased by about 25%. Total loss of the total acidity was about 30%. So, the character of changes is caused by a quick mass transfer into the bean and gradual moisture evaporation along with acidic substances. A similar range of acidity decrease was obtained by Nebesny and Rutkowski [7,8] and Krysiak [4].

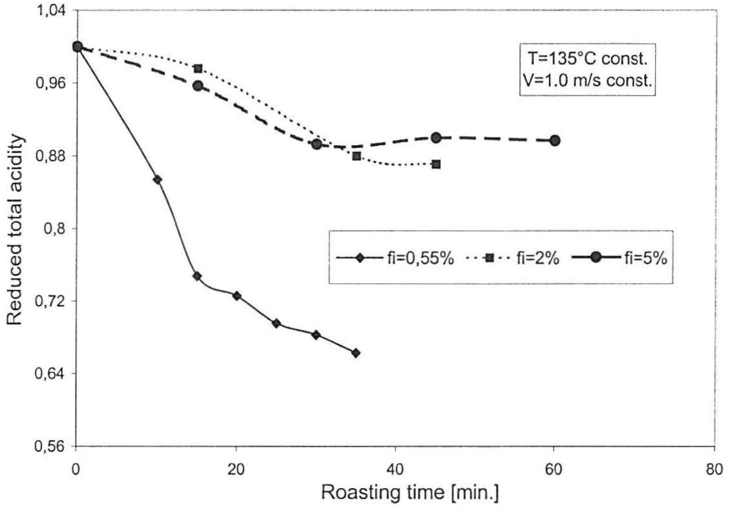

Fig. 2. Changes of total acidity in the cocoa bean depending on the applied roasting conditions.

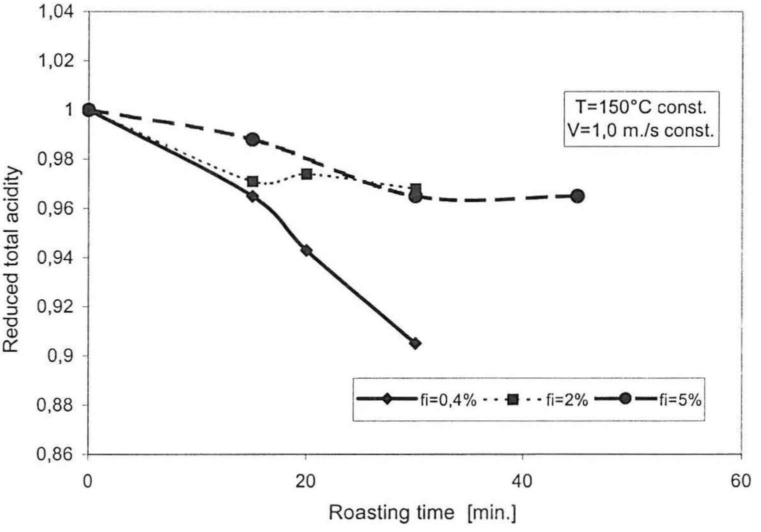

Fig. 3. Changes of total acidity in cocoa bean depending on the applied roasting conditions.

When air with increased relative humidity was used in roasting, it had an unfavourable effect on the final values of total acidity and the way of this removal. The total loss of acidity depended on relative air humidity and was equal to 14 or 9% for relative air humidity 2 and 5%, respectively. As for relationships discussed previously for the temperature 110°C in the air with increased humidity, and also for the temperature 135°C, in the initial period of the process, i.e. up to 20 minutes an abrupt loss of acidity is observed. In the next stage of this process, because of high vapour pressure in the air, the process of removal of acidic substances is hampered and practically the acidity remains on a constant level.

When curves shown in Fig. 3 are analysed, it is found that their character is similar to that of the curves presented in Fig. 2. A result of roasting the cocoa bean with the air of temperature T = 150°C is a decrease of total acidity by 4 to 10%, depending on the relative air humidity. These higher final acidities can be a result of a relatively short period of roasting, but may be caused also by chemical changes induced by high temperature which can be a consequence of oxidation of other compounds present in the cocoa bean. This is confirmed by the research carried out by Lopez and Quensnel [6] and Jinap and Dimick [2].

Volatile acidity

Figures 4, 5 and 6 illustrate changes of volatile acidity in the cocoa bean roasted in the air of variable parameters. On the basis of the analysis of curves it was found that in the case of this quality coefficient of the cocoa bean its decrease

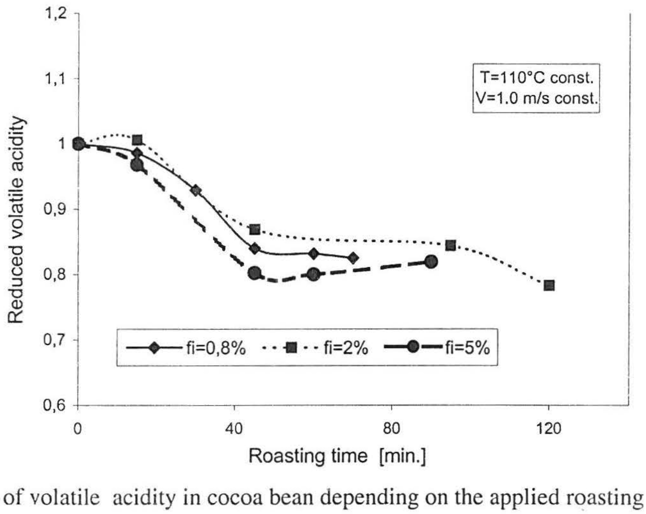

Fig. 4. Changes of volatile acidity in cocoa bean depending on the applied roasting conditions.

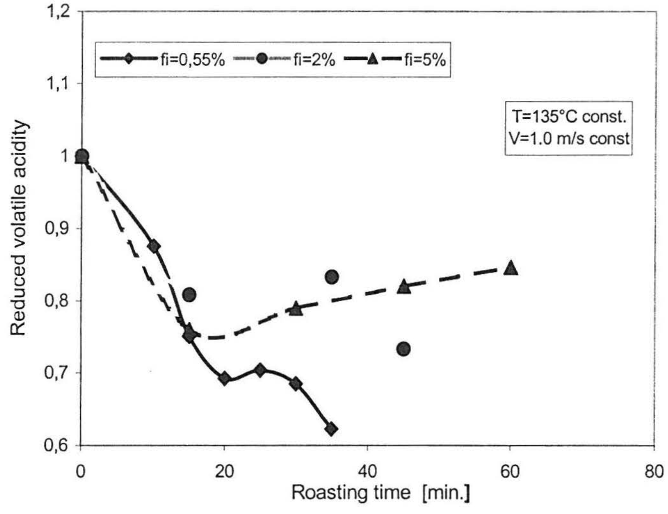

Fig. 5. Changes of volatile acidity in cocoa bean depending on the applied roasting conditions.

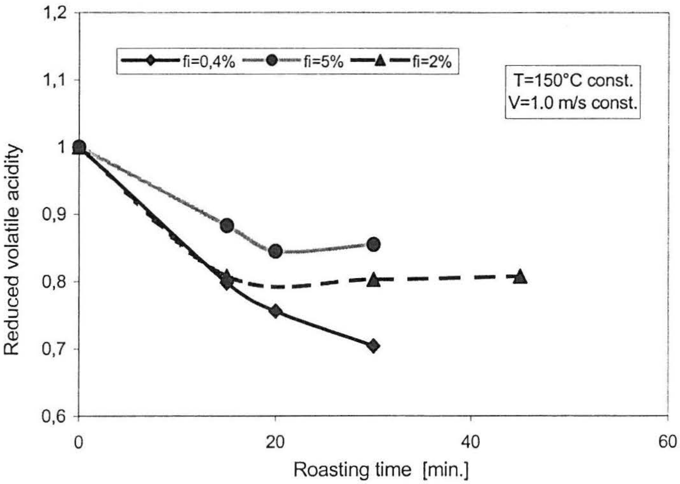

Fig. 6. Changes of volatile acidity in cocoa bean depending on the applied roasting conditions.

is also observed during the process of roasting. As in the case of total acidity, the rate of changes depends on the applied air temperature and its relative humidity. Relationships shown in the Figures are similar to those obtained for total acidity.

It should be stressed, however, that the obtained level of volatile acidity decrease was higher, reaching 40 to 20%. The range of changes in the volatile acidity obtained in this study conforms to the data quoted by Lopez [5], Jinap and Dimick [3] and Nebesny and Rutkowski [7,8].

CONCLUSIONS

On the basis of the obtained results it may be concluded that when the process of roasting is carried out for the whole time in the air with elevated relative humidity (φ = 2 or 5%) it has a negative effect on the removal of substances responsible for total and volatile acidity from the cocoa bean. The most advantageous for the tested cocoa bean variety and the applied experimental rig appeared to be roasting in the air at temperature 135°C, flow velocity v = 1.0 m/s and relative humidity φ = 0.55%.

ACKNOWLEDGEMENT

This work was supported by the State Committee of Scientific Research,
grant No 5 PO6G 023 19.

REFERENCES

1. **Jinap S.,Wan Rosli W. I., et al.:** Effect of roasting time and temperature on volatile component profiles during nib roasting of cocoa beans (Theobrome cacao). J. Sci. Food Agric., 4, 441-448. 1998.
2. **Jinap S., Dimick P.S.:** Acidic characteristics of fermented and dried cocoa bean from different countries of origin. J. Food Sci., 53, 547-550, 1990.
3. **Jinap S., Dimick P.S.:** Effect of roasting on acidic characteristics of cocoa beans. J. Food Sci., 54, 317-321, 1991.
4. **Krysiak W.:** Physico-chemical changes in cocoa bean roasted in changing air coditions.In Properties of Water in Foods. Proceedings of the XII-th Seminar (ed. P.P. Lewicki), Warsaw Agricultural University Press, 107-119, 2001.
5. **Lopez A. S.:** Factors associated with cacao bean acidity and the possibility of its reduction by improved fermentation. Rev. Theobroma, 13, 233-248, 1983.
6. **Lopez A. S., Quesnel V. C.:** Volatile fatty acid product in cacao fermentation and the effect on chocolate flavour. J. Sci. Food Agric., 24, 319-326, 1973.
7. **Nebesny E. Rutkowski J.:** The effect of roasting and secondary fermentation on cocoa bean enrichment. Pol. J. Food Nutr. Sci., 3, 437-444, 1998.

8. **Nebesny E. Rutkowski J.**: Effect of cocoa bean enrichment and chocolate mass conching on the composition and properties of chocolates. Pol. J. Food Nutr. Sci., 4, 673-682 1998.
9. PN, (Polish Standard) 1959/A-88022. Confectionery products. Ash content determination. (in Polish). Wydawnictwa Normalizacyjne, Warszawa., 1959.
10. PN, (Polish Standard) 1971/A-88021. Confectionery products. Fat content determination (in Polish). Wydawnictwa Normalizacyjne, Warszawa.
11. PN, (Polish Standard) 1979/A-88024. Confectionery products. Acidity determination (in Polish). Wydawnictwa Normalizacyjne, Warszawa.
12. PN, (Polish Standard) 1998/A-76101 Cocoa beans - sampling and analytical methods (in Polish). Wydawnictwa Normalizacyjne, Warszawa.
13. **Struszczyński M.**: Technical and qualitative analysis (in Polish), PWT, Warszawa, t. III, 531-533, 1954.
14. **Świechowski Cz.**: Thermal processing of cocoa beans (in Polish). Przegląd Piekarski i Cukierniczy, 1, 35-37, 1994,
15. **Świechowski Cz.**: Chocolate production. Roasting of cocoa beans - comparison of different methods (in Polish). Przegląd Piekarski i Cukierniczy, 4, 20-22, 1996,
16. **Wyczański S.**: Confectionery production. (in Polish). WSiP, Warszawa, 249-252, 257; 264, 1990.

WARUNKI PRAŻENIA A JAKOŚĆ ZIARNA KAKAOWEGO

W. Krysiak

Instytut Chemicznej Technologii Żywności, Politechnika Łódzka
ul. Stefanowskiego 4/10, 90-924 Łódź
e-mail: krysia@snack.p.lodz..pl

Streszczenie. Ziarno kakaowe gatunku Ivory Coast zostało poddane procesowi prażenia powietrzem o temperaturze 110, 135 i 150^{0}C, prędkości przepływu v = 1,0 m/s oraz wilgotności względnej (0,55-0,4),2 i 5%. W czasie procesu termicznej obróbki w ziarnie określano zawartość wody, a także kwasowość ogólną i lotną. Na podstawie uzyskanych wyników stwierdzono, że prowadzenie przez cały czas procesu w powietrzu o podwyższonej wilgotności względnej (φ = 2 lub 5%) przyczynia się do obniżenia w znacznie mniejszym stopniu kwasowości ogólnej i lotnej niż ma to miejsce gdy stosowano powietrze „suche" (0,55-0,4).

Słowa kluczowe: ziarno kakaowe, prażenie, kwasowość ogólna i lotna, jakość ziarna kakaowego.