

Changes in aromatic components of banana during ripening and air-drying

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Abstract

Fresh and dried bananas were extracted by solid phase micro-extraction (SPME) and analysed by gas chromatography (GC). The effect of the geographic origin of the fruit on aromatic composition was first examined. Twelve aromatic compounds (2 alcohols, 9 esters and 1 phenol) were identified by GC-MS. The aromatic changes of *Cavendish* banana was then studied during ripening and drying. Seven volatile compounds, four among the previous 12 (Isoamyl alcohol, Isoamyl acetate, Butyl acetate and Elemicine) and three other nonidentified compounds were selected by olfactometric analysis as characteristics of banana smell. The seven selected aromatic compounds were analysed during convective air-drying at 40°C, 60°C and 80°C.

The entraining of aromatic compounds by water vapor was the main mechanism that occurred during the first 2 h of drying. It is suggested that Maillard reaction products were developed at the end of drying at 80°C. Some compounds strongly decreased during drying (Isoamyls) whereas other nonidentified compounds were partly retained. Elemicine was found to be the most thermal resistant one. Changes in aromatic components were dependent on the moisture content of the pulp (X_{pl}) and on the air-drying temperature (T_a).

Keywords: Banana; Aroma; Drying; Olfactometric analysis; Entraining by water vapor

1. Introduction

Banana is a staple constituent in the diet of inhabitants of the regions where harvested. It is often consumed fresh and sometimes processed to produce new ingredients (snacks, puree, etc.). Fresh banana changes rapidly after harvesting and the color, firmness and flavor of the fruit are always damaged during storage (Collin & Dalnic, 1991). Many studies have been performed on fresh banana in order to define optimal storage conditions so as to increase its shelf-life (Collin & Dalnic, 1991; Ueda, Tsuda, Bai, Fujishita, & Chanchin, 1992; Kojima, Naoki, Susumu, & Akira, 1994; Kojima, 1996; Salmon, Martin, Remaud, & Fourel, 1996; Meng, Slaughter, & Thompson, 1997; Prabha & Bhagyalak, 1998; Golding, Bhearer, Mc Glasson, & Wyllie, 1999). Kojima (1996) suggested that changes in the firmness of fresh banana during ripening

were due to the decrease of the amount of some chemical components of the cell wall of banana peel (polysaccharides, pectin and hemicelluloses) and of the starch in the pulp of the fruit. Salmon et al. (1996) studied the molecular and isotopic composition of the aromatic content of banana from different origins, at different states of ripeness. The author showed that it was possible to follow the process of ripening of the fruit by determining the isotopic and molecular composition of alcohols present in the pulp of banana. He also showed that Isoamyl acetate, pentan-2-one and Isoamyl butyrate were characteristics of the geographic origin of the fruit. The color of the peel is often used as a rapid measurement to characterize the state of ripeness of banana fruit (Collin & Dalnic, 1991; Meng et al., 1997).

Drying stabilizes the product by decreasing its water activity and moisture content, but the quality of the fruit and particularly its flavor is sensitive to heat treatment. In fact, aromatic components are lost during drying and other undesirable components can be formed. In the few published papers dealing with the study of the kinetics of aroma changes during dehydration

Nomenclature	GC-O	gas chromatography coupled to olfactometric analysis
t	time (h)	
T_p	product temperature (°C)	
TRA_{DM}	total relative area/kg DM	
PA_{DM}	peak area/kg DM	
X_{pl}	Moisture content of the pulp (kg water/kg DM)	
<i>Abbreviations</i>		
DM	dry matter	
FID	flame ionization detector	
GC	gas chromatography	
	MS	mass spectrometry
	PDMS	polydimethyl siloxane
	SPME	solid-phase micro-extraction
	<i>The 7 volatile compounds analysed during drying</i>	
	Iso Al	Isoamyl alcohol
	Bu Ac	Butyl acetate
	Iso Ac	Isoamyl acetate
	Ele	Elemicine
	NI 1, NI 2 and NI 3	nonidentified volatile compounds 1, 2 and 3

Table 1
Main studies dealing with the kinetics of volatile content of some products during dehydration

Process/product	Operating parameters	Successive changes in aromatic components: observations → suggested mechanisms
<i>Hot air drying</i>		
Mushrooms (Le Loch-Bonazzi et al., 1992)	Temperature (°C): 40–60 Time (h): 16.5–21.5	Slight increase/decrease or disappearance/retention of volatiles
Bell peppers (Luning & Ebbenhorst-Seller, 1995)	Temperature (°C): 35–40 Time (h): 30–40	→ Generation of volatile by enzymic reactions during ripeness of the product, anaerobic respiration/entraining by water vapor, Maillard reaction and Strecker degradation
Peanut kernels (Osborn et al., 1996)	Temperature (°C): 65 Time (h): until 0.1 kg of water/kg DM	
<i>Freeze drying</i>		
Mushrooms (Le Loch-Bonazzi et al., 1992)	Pressure (Pa): 50,500–101,300 Time(h): 16	Slight increase/decrease or disappearance/retention of volatiles
Bananas (Cosio, 1997)	Pressure (Pa): 5–200 Temperature (°C): 20–60 Time (h): 21–40	→ Generation of volatile by enzymic reactions during ripeness of the product/entraining by water vapor/immobilization of volatile in the monolayer

(Le Loch-Bonazzi, Wolff, & Gibert 1992; Luning & Ebbenhorst-Seller, 1995; Osborn, Young, & Singleton 1996; Cosio, 1997) different effects of the process are described (Table 1). Generally, the changes in volatile components showed three consecutive phases. These authors observed a slight increase followed by a strong decrease of the aromatic content in the beginning of the dehydration. The amount of volatiles remained thereafter stable or decreased until the end of the process. The increase of the aromatic content was explained by the development of some reactions (anaerobic respira-

tion, ripeness or enzymic generation of volatiles) at low temperatures and generally at the beginning of the process during which the moisture content of the product is still high. While the loss of aromatic content was often attributed to the evaporation of volatile components from the product, Maillard reaction and Strecker degradations have been suggested to explain the increase of the aromatic content during the process carried at high temperatures. Several authors showed that the changes in aromatic content were affected by the operating parameters of the process (temperature,

pressure) and by the initial state of ripeness of the product (Luning & Ebbenhorst-Seller, 1995; Osborn et al., 1996; Cosio, 1997).

In this study, aroma compounds of fresh banana from different geographic origins (Martinique, Canary Islands and Ivory Coast) were first examined. *Cavendish* banana from Martinique was then retained for next investigation. Olfactometric analysis of extracts of fresh and dried banana was performed in order to select components to be studied during drying. The influence of the air temperature on the selected aromatic components was then investigated.

2. Experimental procedure

2.1. Raw material

Banana was purchased from a local supermarket and stored at room temperature. A commercial peel color scale (Chiquita[®], Brands, Inc) (Fig. 1) was used to select homogenous and high-quality bananas according to the color of the peel.

The moisture content of the pulp (X_{pl}) was measured by gravimetry before and after dehydration for 24 h in

an oven at 105°C. Moisture content of the pulp (X_{pl}) was expressed in kg water/kg dry matter.

2.2. Banana characterization

The degree of ripeness of *Cavendish*, Grande Naine banana (from Martinique) was first of all monitored during storage at room temperature and humidity (from color peel index 3 (more green than yellow) to 7 (overripe)). The parameters discriminating between degrees of fruit ripeness are: sugar content in the pulp, firmness of the banana with peel (S) and peel color (a^*). Two nonlinear regression models made it possible to link S and a^* to storage time. Glucose content was correlated with the magnitudes S , a^* and X_{pl} in order to be able to work without actually taking this measurement when it came to characterizing the raw material (Boudhrioua, Michon, Cuvelier, & Bonazzi, 2002).

2.3. Drying of banana

Yellow bananas of peel color index of 6 on the Chiquita[®] color scale were used to carry out drying experiments. The moisture contents of bananas used for drying experiments at 40°C, 60°C and 80°C were, respectively, 3.3, 3.5 and 4.3 kg water/kg DM which corresponded to a glucose content of ≈ 4.5 g/100 g of fresh banana estimated using the correlations mentioned above.

Drying experiments were conducted in a vertical airflow drier previously described by Abud Archila, Courtois, Bonazzi, and Bimbenet (2000). The experiments were carried out at constant conditions, using thin layers of banana slices of 5 mm thickness (≈ 160 g). The experiments were carried out at constant air velocity (2 m/s), without steam injection and at air temperatures of 40°C, 60°C or 80°C, which corresponded respectively to air humidity of 15%, 5% and 3%, over a period of 24 h. Banana slices, sampled from the drier at different times (0.5, 1, 1.5, 2, 6 and 24 h), were weighed with precision (± 0.1 mg) before the aroma analysis. Each experiment was repeated twice.

The monitoring of the internal (using a thermocouple in the center of a slice) and surface (using an infrared sensor) temperatures of the product showed that the difference between both temperatures was not significant. The temperature of the product was therefore estimated directly from the surface temperature.

2.4. Extraction method

The aroma fraction of banana was isolated by solid phase micro-extraction (SPME, holder 57331, ©Sigma—Aldrich, Bellefonte, PA, USA). Banana slices were homogenized in a blender, weighed with precision and then placed in 15 mL vial, which was then crimped,

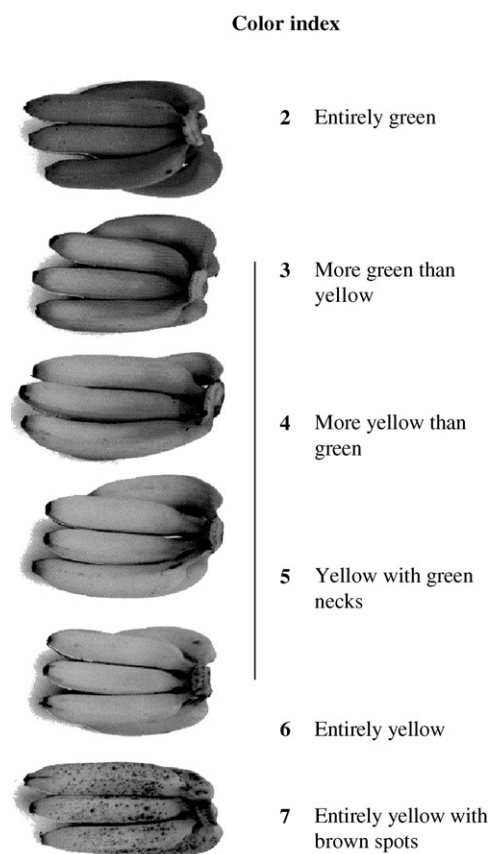


Fig. 1. Commercial peel color scale (Chiquita[®], Brands, Inc.).

capped using a silicone Teflon-lined septum. A stainless-steel needle housing the fiber penetrated the septum. The fiber was then pushed into the headspace above the sample for extraction at 60°C for 30 min. A 10 mm length polydimethyl siloxane (PDMS) fiber (Supelco[®], Sigma—Aldrich, Bellefonte, PA, USA) was used.

2.5. Chromatographic and spectrometric conditions

Sample analysis was carried out with a Hewlett–Packard 5890 gas chromatograph (GC) equipped with a flame ionization detector (FID). A DB5 (95% of methyl and 5% of phenyl siloxane) column (J & W Scientific Inc., 25 m, 0.32 mm i.d., 0.52 µm thickness) was used. Helium was used as carrier gas at a flow rate of 1.2 mL/min. Thermal desorption of the compounds from the fiber took place in the GC split/splitless injector at 250°C. The oven temperature was programmed from 35°C (1 min) to 250°C at 4°C/min and was maintained 5 min at 250°C. The volatile compounds were analysed by mass spectrometry (MS, Trio 1000, Fison, VG Masslab, Manchester) (Electronic impact (EI) 70 eV, quadrupolar filter) and identified by comparison with spectra stored in a data bank. This identification was confirmed using the retention indexes calculated on an alkan solution (C₆–C₂₂) injected in the same conditions.

Preliminary experiments also showed that aroma extracts could be stored for 2 h at 5°C without significant loss of aromatic content in comparison with a reference, which was analysed just after extraction (Fig. 2). This procedure was applied on the samples collected during the first 2 h of drying because of the large time of GC analysing (≈2 h). The variation of aromatic compounds amounts of banana were evaluated using, respectively, the total relative area (TRA_{DM}) and the area of the peak (PA_{DM}) of each compound divided by the dry matter of the sample.

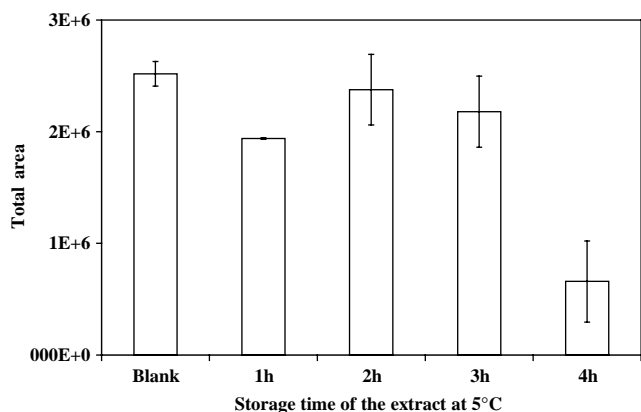


Fig. 2. Aroma content during storage of the banana extracts at 5°C (3 repetitions).

Total relative area (TRA) = Total area_t/Total area_{t₀}, with Total area (TA) = sum of the areas of all peaks of the chromatogram calculated at t₀ (in fresh banana) and after a drying time t.

2.6. Olfactometric conditions

The Osme method as proposed by Mc Daniel (Da Silva, Lundahl, & Mc Daniel, 1994) was applied using a GC equipped with an olfactometric analysis detector (GC-O/FID, Hewlett–Packard 5890, série II). This method consisted in evaluating directly the intensity of each odor by trained subjects (Lopez, Libbey, Watson, & Mc Daniel 1992; Pollien et al., 1997; Ibanez, Lopez-Sebastien, Ramos, Tabera, & Reglero, 1998). The intensity was scored by the subjects between 0 and 100 with a scale as described by Hanaoka, Sieffermann, and Giampaoli (2000).

Experiments were performed using the same GC conditions as described above. At the end of the column, carrier gas flow was split into two equal parts, one going to the FID (T = 250°C) and the other one going to the sniffing port (T = 220°C).

The panel was made up of 4 subjects. The subjects were trained during two sessions in order to get familiar with the apparatus and to test if they were able to detect and to distinguish different molecules injected in different concentrations.

They were first trained using one reference molecule (ethyl butyrate) dissolved in ethanol at different concentrations and injected in random order, then with an ethanolic solution of 5 compounds (octanol, citronellal, nonanal, phenylethyl acetate and 3-methyl butanethiol). Satisfactory results were obtained for the 4 subjects because the sensorial intensity detected was proportionnal to the concentration of the ethyl butyrate and no anosmia had been detected during the training phase.

They were retained then for the analysis of the extracts of fresh and dried banana (dried 24 h at 80°C).

3. Results and discussions

3.1. Analysis of the flavor of fresh banana

3.1.1. Identification

Aromatic composition of yellow bananas (peel color index 6 on the Chiquita[®] color scale) from different varieties and origins were examined (*Musa acuminata* species, *Cavendish* group, Grande Naine variety (from Martinique and Ivory Cost); small Naine (from Canary Islands)). Different aromatic profiles were observed according to the geographic origin and variety of the bananas. More than one hundred of compounds were separated by GC. The highest amount of volatile

compounds was obtained for banana from Martinique (Fig. 3). Among the numerous separated compounds, twelve were identified from the literature as the most significant compounds of banana smell (2 alcohols, 9 esters and 1 phenol) (Table 2). Other authors (Ueda et al., 1992; Salmon et al., 1996; Cosio, 1997) had previously described these compounds as typical of the fresh banana flavor. Isoamyl acetate was often considered as the main aroma constituent characterizing fresh banana. In addition, Salmon et al. (1996) reported that esters constituted the main fraction of volatile emission of fresh banana.

Only *Cavendish* Grande Naine banana (from Martinique) was then retained to be studied during ripening (from color peel index 3 (more green than yellow) to index 7 (overripe)).

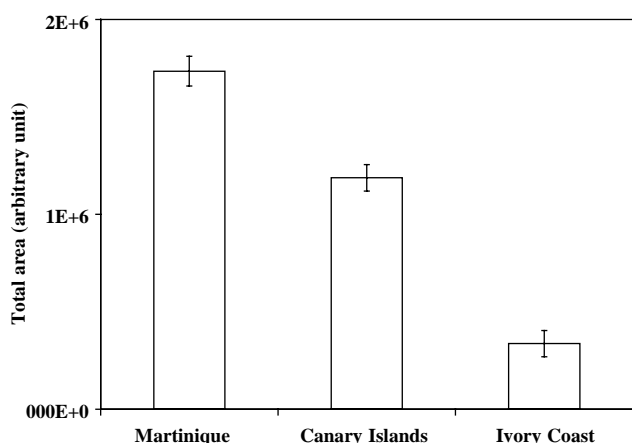


Fig. 3. Aroma content of yellow banana from different geographic origins (3 repetitions).

Table 2

Twelve volatile compounds identified in banana

Volatile compounds	Retention time (min)	Fraction of components in fresh banana ^a (%)	Descriptors ^b
Isoamyl alcohol ^c	4.7 ± 0.3	3.37 ± 0.004	Pungent
Butyl acetate ^c	5.5 ± 0.1	0.68 ± 0.01	Fruity
Isoamyl acetate ^c	7.3 ± 0.1	5.32 ± 0.02	Fruity
NI1 ^c	9.3 ± 0.1	0.08 ± 0.0003	Burning, Dried fruit
NI2 ^c	22.2 ± 0.2	0.1 ± 0.0001	Burning, Dried fruit
NI3 ^c	26.5 ± 0.1	0.31 ± 0.001	Burning, Dried fruit
Elemicine ^c	31 ± 0.2	0.050 ± 0.0004	Fruity
Isopropanol (2-propanol)	0.9 ± 0.2		
Ethyl acetate	1.5 ± 0.1		
Butyl butyrate	11.7 ± 0.1		
Isoamyl isobutyrate	12.1 ± 0.1		
Isoamyl butyrate	13.9 ± 0.1		
Isoamyl 2 methyl butyrate	15.7 ± 0.1		
Isoamyl valerate	15.9 ± 0.1		
Isoamyl caproate	21.3 ± 0.1		

^aFractions of components in fresh banana (%) = $\frac{\text{Area of the peak of a component in fresh banana}}{\text{total area of all components in fresh banana}}$.

^bDescriptors given by the subjects.

^cComponents analyzed during drying.

3.1.2. Change of aromatic compounds during storage at room temperature

Fresh yellow/green bananas (peel color index 3 on the Chiquita[®] color scale) from Martinique were analysed during 7 days of storage at room temperature. More than one hundred compounds were separated by GC. Among the 12 components identified as the most significant of banana smell only Isoamyl acetate, Butyl acetate and Elemicine were detected at d_0 (day of purchase corresponding to peel color index 3 on the Chiquita[®] color scale). Concentrations of the aromatic compounds increased progressively during storage. The total area of the peaks increased from 0.5×10^6 AU (AU: arbitrary unit) to 2×10^6 AU after 7 days of storage at room temperature. Fig. 4 shows the chromatograms patterns obtained for yellow/green and overripe bananas. Only some compounds were detected for yellow/green bananas with two major peaks corresponding to Isoamyl acetate and Butyl acetate, whereas numerous peaks were detected for overripe bananas and the areas of the peaks strongly increased. Such an increase of the aromatic content of bananas during ripening had also been observed by Salmon et al. (1996). The authors suggested that the increase in aromatic content of banana during ripening was due to the biosynthesis process of volatile components from amino acids such as valine and leucine and to β -oxidation, which is the main degradation process of fatty acids during ripening.

3.2. Olfactometric analysis

In the few papers so far published and dealing with studies of the effect of drying on aromatic quality of the

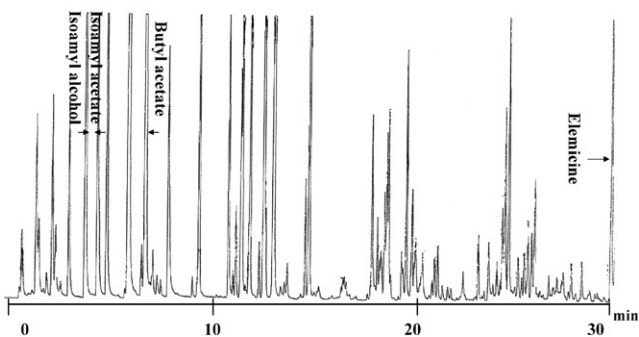
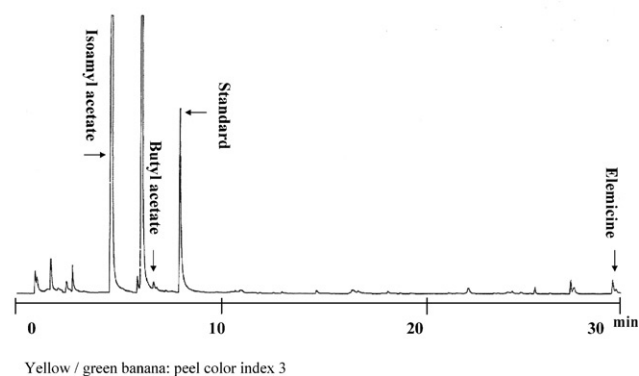


Fig. 4. Chromatograms patterns of yellow/green (Peel color index 3) and overripe (peel color index 7) bananas (*Cavendish*, Martinique).

product (Table 1), the selection of aromatic components analysed during drying was based on the numerous components reported in the literature as characteristic of fresh product without any a priory olfactometric analysis. Others components may however be developed during hot air-drying, affecting the quality taste of dried banana.

In this work, olfactometric analysis was carried out in order to select components characteristics of the aromatic quality of fresh and dried banana. The panel of four subjects consistently detected only 7 compounds during olfactometric analysis of banana extracts. Four compounds (Isoamyl alcohol, Isoamyl acetate, Butyl acetate and Elemicine) were detected in fresh banana and three other nonidentified compounds were detected in dried banana. The subjects attributed odors of fresh banana and notes of fruits to Isoamyl acetate and to Butyl acetate whereas burning notes were attributed to the three nonidentified compounds (Table 2). The panel attributed higher odor intensities to Isoamyl acetate and Butyl acetate in fresh banana (63% and 56%) and to the three nonidentified compounds in dried banana for 24 h at 80°C (>40%). A variance analysis of the intensities attributed by the panel to fresh and dried extracts (24 h at 80°C) was performed (Table 3). There was no significant difference between intensities recorded for Isoamyl alcohol, Isoamyl acetate, Butyl acetate and Elemicine in fresh and dried extracts.

Table 3

Results of the variance analysis of the average intensities attributed for the 7 volatile compounds by the panel on dried and fresh banana

Parameters	Level of significance of the drying	<i>P</i> -value at 95%
Isoamyl alcohol	*	0.3
Butyl acetate	*	0.06
Isoamyl acetate	*	0.2
NI1	**	0.004
NI2	**	0.004
NI3	**	0.009
Elemicine	*	1

* $P < 0.05$ and ** $P < 0.01$.

3 repetitions for each subject.

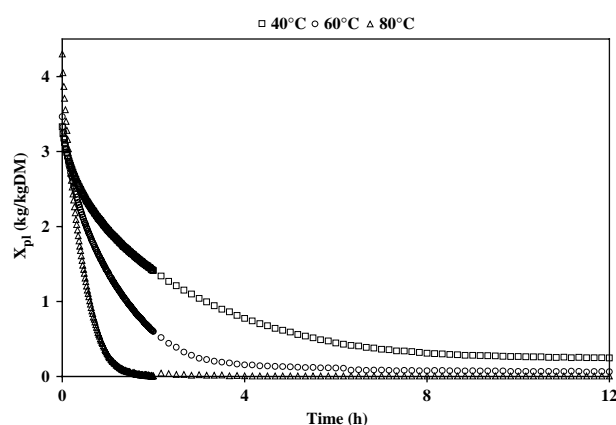


Fig. 5. Moisture of the pulp (X_{pl}) during air-drying at 40°C, 60°C and 80°C.

3.3. Analysis of the flavor of banana during air-drying

The variations in aromatic compounds amounts of *Cavendish* banana were examined as a function of drying time at 40°C, 60°C and 80°C.

3.3.1. Drying kinetics

The changes in moisture content of the pulp (X_{pl}) versus time of drying for different air temperatures are shown in Fig. 5. Two drying phases can be distinguished. The moisture content strongly decreased during the first 2 h and then decreased more slowly until the end of drying. The final moisture content was about 0.25, 0.06 and 0.006 kg/kg DM after 24 h of drying, respectively, at 40°C, 60°C and 80°C.

Fig. 6 shows the course of the air temperature (T_a) and the temperature of the product (T_p). It shows that for all the tested air temperatures (40°C, 60°C and 80°C), after 2 h of drying the temperature of the product reached the temperature of the air regardless of the air temperature and then the curves superposed. The changes in aromatic composition are doubtless affected

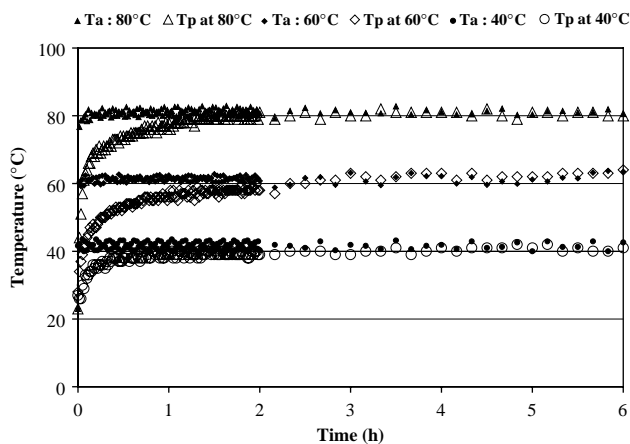


Fig. 6. Product temperature (T_p) and air temperature (T_a) during air-drying at 40°C, 60°C and 80°C.

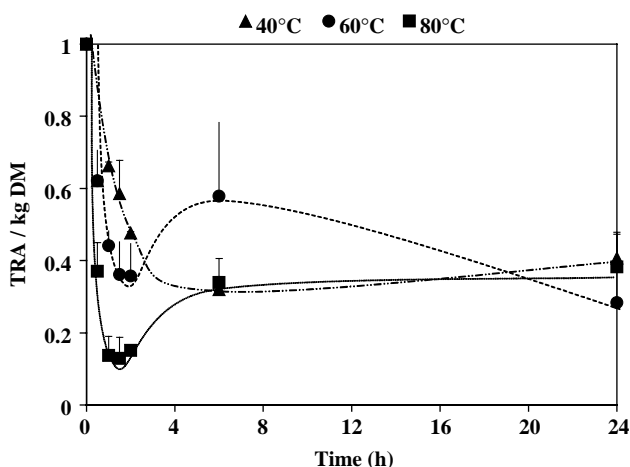


Fig. 7. Total relative area (TRA_{DM}) of *Cavendish* banana versus time during air-drying at 40°C, 60°C and 80°C (2 repetitions).

by the changes in temperature of the product during drying.

3.3.2. Changes in total aromatic content during drying

Fig. 7 shows the changes in total relative aromatic content expressed as the relative total area per kg of dry matter (TRA_{DM}) versus time. The aromatic content decreased sharply during the first 2 h of drying and all the more since the air temperature is higher. The speed of entraining of flavoring molecules by water vapor was slowed down after the first 2 h of drying. A slight increase in TRA_{DM} was observed between the 2nd and the 6th hours of drying at 60°C and 80°C, and then TRA_{DM} decreased again (at 60°C) or remained unchanged (at 80°C). The final level of TRA_{DM} was higher at 40°C than at 60°C. The difference between final levels of TRA_{DM} observed between 40°C and 60°C (Fig. 7) can be explained by the difference in partial vapor pressures between the product and the air which was

smaller at 40°C. Consequently, more aromatic compounds were retained at the end of drying at 40°C. The increase in TRA observed at the end of drying at 80°C corresponded to a water content of a banana (X_{pi}) less than 0.006 kg/kg DM and to a temperature of product (T_p) around 78°C. The increase of the TRA_{DM} at the end of drying at 80°C could be due to the emergence of cooking or Maillard reaction products. In fact, Maillard reactions between amine and carboxyl functions are favored at high temperature (more than 60°C) and at low water contents (less than 0.5 kg/kg DM). Indeed a banana is rich in sugars (glucose, fructose, etc.) and peptides, substrates required for the Maillard reactions (Koehler, Masson, & Newell, 1969).

The entraining of volatile compounds by water vapor was the preponderant phenomenon during the first 2 h of drying. The loss in aromatic components was also observed by Le Loch-Bonazzi et al. (1992) during dehydration of mushrooms, by Luning and Ebbenhorst-Seller (1995) during air-drying of Bell peppers, by Osborn et al. (1996) during air-drying of peanut kernels and by Cosio (1997) during freeze-drying of bananas.

Thijssen and Rulkens (1969) showed that the diffusivities of volatile compounds compared to that of water decreased more rapidly when water content of the product decreased. The authors explained the last observation by a selective diffusion of water and the volatile compounds in the dry layer. Such retention of volatile compounds was also observed by Cosio (1997) and Le Loch-Bonazzi et al. (1992), respectively, at the end of freeze-drying of bananas or mushrooms.

3.3.3. Changes in aromatic compounds

The aromatic compounds were classified into two groups according to their amounts in fresh banana to make easier the comparison of their kinetics.

The first group was made up of Isoamyl alcohol (Iso Al) and Isoamyl acetate (Iso Ac), which existed in high amounts in fresh banana. The second group contained Butyl acetate (Bu Ac), Elemicine (Ele) and the three nonidentified compounds (NI 1, NI 2 and NI 3), which existed in small quantities in banana extracts. The highest odor intensities in dried banana were attributed by the panel to the nonidentified compounds (Table 3). These nonidentified compounds which existed in small concentrations in dried banana extracts and were characterized by burning notes could no be detected by mass spectrometry. These components could have been developed by cooking or Maillard reactions and had probably extremely low sensory detection thresholds.

Fig. 8 showed the changes in the areas of the peaks of each compound at different times of drying. A fast and strong decrease was observed for the Isoamyl alcohol and Isoamyl acetate during the first 2 h of drying.

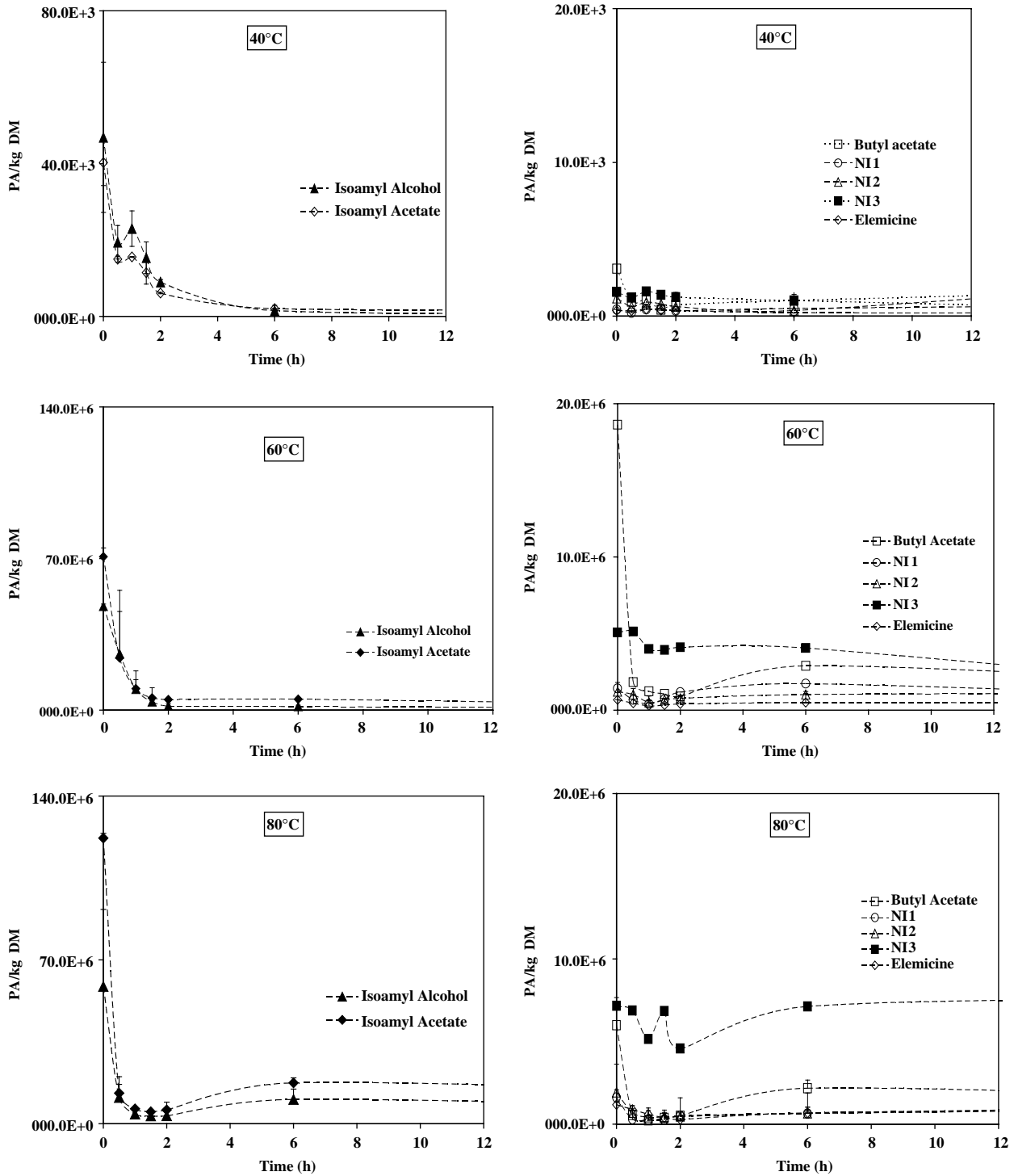


Fig. 8. Changes in the amounts of the seven aromatic components of *Cavendish* banana during air-drying at 40°C, 60°C and 80°C (2 repetitions).

Different effects of drying could be distinguished on the compounds of the second group. Their variations were more difficult to interpret because of their small amounts in banana extracts. Some compounds were partly retained (NI 1, NI 3). These compounds seemed to be formed at the end of drying at 80°C. Butyl acetate decreased continuously during drying. Elemicine con-

centration remained unchanged whatever the air temperature. It was found to be resistant to thermal treatment. There was no significant difference between intensities attributed by the panel to Elemicine in both fresh and dried bananas (Table 3).

Fig. 9 shows the difference between chromatograms profiles obtained for fresh banana (yellow: peel color

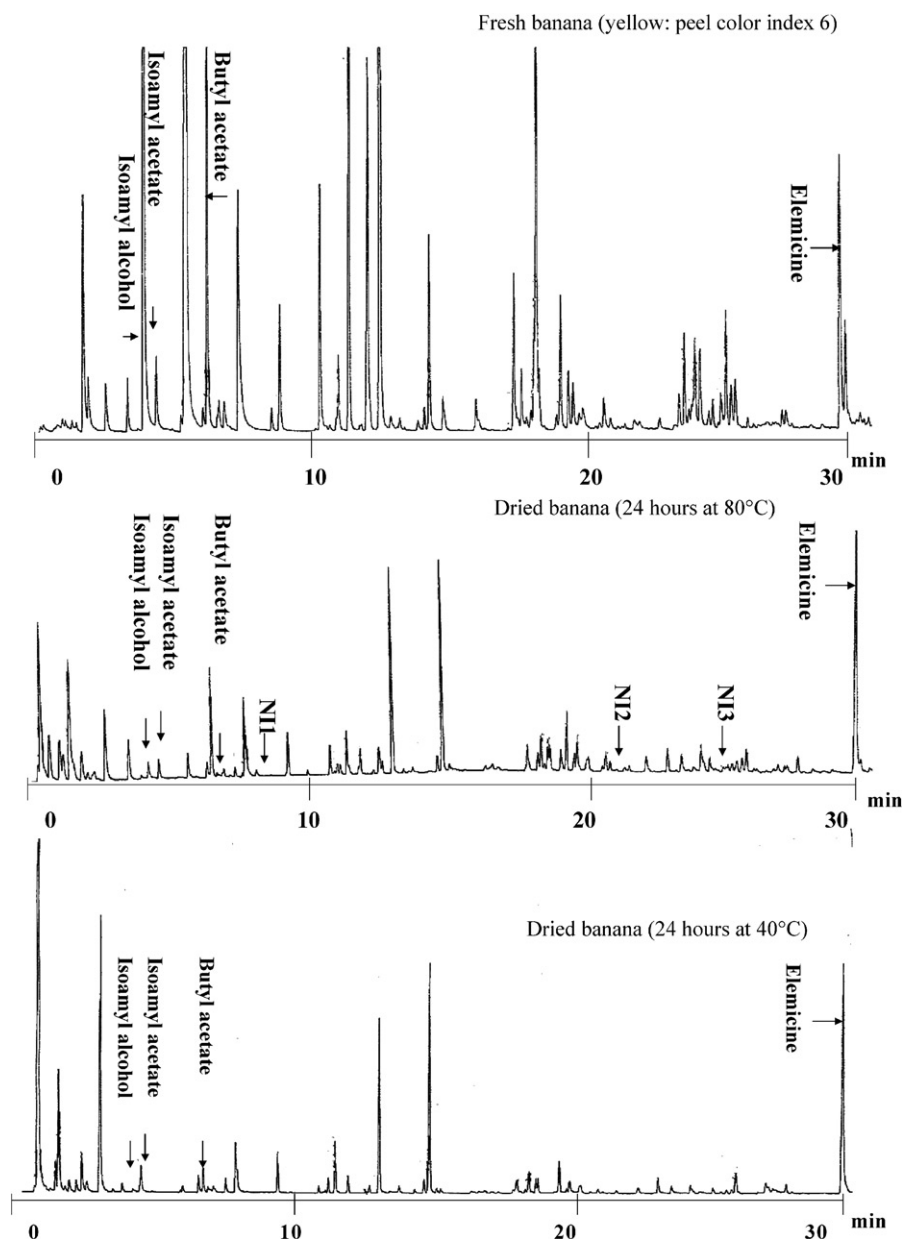


Fig. 9. Chromatograms patterns of yellow fresh banana (Peel color index 6) and dried banana 24 h at 40°C and 80°C.

index 6) and dried bananas 24 h at 40°C and 80°C. The areas of the volatile compounds (Isoamyl alcohol, Isoamyl acetate and Butyl acetate) sharply decreased after 24 h of drying whereas Elemicine remained unchanged. Others peaks were found to appear on the chromatogram of bananas dried 24 h at 80°C. The panel detected at 9.3, 22.2 and 26.5 min three compounds for which they attributed burning notes.

Similar changes in total aroma content (TRA_{DM}) and for each aromatic compound (PA_{DM}) were observed during drying: a sharp decrease at the beginning of drying whatever air temperature and then a slight increase at the end of drying at 60°C and 80°C. The seven aromatic compounds identified by

the panel in banana extracts could be considered as good indicators of the aromatic quality of a banana.

The level of air temperature (T_a) and the changes in moisture content of the banana (X_{pi}) affected differently the kinetics of the loss of aromatic content of bananas. During drying different phenomena may be suggested: entraining by water vapor, which prevailed in the first 2 h of drying, and then development of Maillard reactions.

4. Conclusion

The aromatic volatile compounds of fresh bananas from different origins and varieties were analysed. The

amount of aromatic volatile compounds increased during ripening at room temperature. Twelve compounds were identified in fresh banana from the literature as the main aromatic banana compounds. Aromatic compounds of *Cavendish* banana were studied during drying. The panel recognized only seven compounds (Isoamyl alcohol, Isoamyl acetate, Butyl acetate, Elemicine and three other nonidentified compounds) on dried and fresh banana extracts during olfactometric analysis. These seven compounds were selected for analysis during air-drying at 40°C, 60°C and 80°C.

Different effects of air temperature were observed on the changes in volatile compounds: a strong decrease during the first 2 h, an increase between the 2nd and the 6th hours of drying at 60°C and 80°C, then a slight decrease at the end of drying at 60°C. A continuous decrease was observed for the Isoamyl acetate, Isoamyl alcohol and Butyl acetate whereas some compounds increased or seemed to be formed at the end of drying (NI 1, NI 3) at 80°C. Elemicine was found to be the most thermal resistant compound. The loss in aromatic content by water vapor entraining was found to be the preponderant phenomena at the beginning of drying whatever the air temperature. It was suggested that cooking and Maillard reactions were developed at the end of drying at 80°C.

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