Available online at www.sciencedirect.com
SCIENCE DIRECT®
Food Chemistry 86 (2004) 553–561
Food Chemistry
www.elsevier.com/locate/foodchem

Characterisation of Egyptian Ras cheese. 2. Flavour formation

E.H.E. Ayad [a,*], S. Awad [b], A. El Attar [b], C. de Jong [c], M. El-Soda [b]

[a] Food Science Department, Faculty of Agriculture, Saba Bacha, Alexandria University, Egypt
[b] Dairy Science and Technology Department, Faculty of Agriculture, Alexandria University, Egypt
[c] NIZO Food Research, Department of Flavour, Nutrition, and Ingredients, P.O. Box 20, Ede, BA 6710, The Netherlands

Received 17 December 2002; accepted 10 October 2003

Abstract

Thirteen samples of commercial Ras cheese made from raw milk at different ripening-times were collected to evaluate the sensory properties and to identify the typical flavour compounds. Cheeses were assessed by sensory evaluation and the rheological properties were determined using a texture analyser. The flavour volatile compounds were identified by the purge-and-trap, thermal desorption cold-trap (TDCT), and gas chromatography mass spectrometry (GC-MS). The sensory results indicated that nine samples were typical Ras cheeses and four samples were not typical. Typical Ras cheeses are tasty, piquant and sharp in flavour, not too hard and not soft in texture and the body includes some mechanical opening and gassy opening and the colour is regular. A good correlation was found between the rheological measurements calculated by machine and the texture score evaluated by panellists. GC-MS analysis revealed that, sixty-eight volatile compounds were detected in Ras cheese samples, including 13 alcohols, 11 aldehydes, 17 ketones, 25 esters and four other compounds, which are responsible for the cheese flavour. There were differences in the concentrations of these aroma-compounds, corresponding with the age of the cheeses. GC-MS data showed a good correlation with the organoleptic descriptions.
© 2003 Elsevier Ltd. All rights reserved.

Keywords: Ras cheese; Flavour formation; Sensory evaluation; Rheological properties; GC-MS analysis; Volatile compounds

1. Introduction

The acceptability of cheese depends on its appearance and sensory properties (flavour, texture, colour). Among these, flavour is the most important attribute for the consumer. Cheese flavour is believed to result from a balance between a number of components released by enzymic reactions rather than by chemical interactions (Delahunty & Piggott, 1995). The characteristics of the flavour profile of ripened cheeses are mainly affected by proteolysis of caseins and in some types also by lipolysis (Adda, 1986; Crow, Coolbear, Holland, Pritchard, & Martley, 1993). The typical cheese flavour results from further degradation of amino acids, due to the pathways for conversion of amino acids by starter bacteria (Brome & Limsowtin, 1998). That is true in cheeses, produced from pasteurised milk and using starter cultures under aseptic conditions. However, cheese ripening is influenced by different factors, including the microflora of the raw milk, coagulant, starter cultures and by adventitious contamination of the cheese by non-starter bacteria (Fox, O'Connor, McSweeney, Guinee, & O'Brien, 1996).

Based on sensory evaluation and chemical analysis of cheeses, various groups of volatile compounds have been identified as being responsible for the final taste and aroma of cheese. These compounds comprise fatty acids, esters, aldehydes, alcohols, ketones, sulphur compounds and various other components (Bosset & Gauch, 1993; Engels, Dekker, De Jong, Neeter, & Visser, 1997; Urbach, 1995; Maarse & Visscher, 1989). Specific definitions for several types of cheese are given in the Code of Fedral Regulations (1990) and over one hundred volatile components identified in various types of cheese are currently listed in the database (Nijssen, Visscher, Maarse, Willemsens, & Boelens, 1996).

* Corresponding author. Tel.: +31-318-659-538; fax: +31-318-650-400.
E-mail address: eayad@hotmail.com (E.H.E. Ayad).

0308-8146/$ - see front matter © 2003 Elsevier Ltd. All rights reserved.
doi:10.1016/j.foodchem.2003.10.002

Ras cheese, the main traditional hard cheese in Egypt, is manufactured in a high proportion under artisan production, in rural areas and small factories, from raw cow's milk or a mixture of cow and buffalo's without using starter cultures (Hofi, Yossef, Ghoneim, & Tawab, 1970). In such production the fermentation occurs by the wild microflora present in raw milk and surrounding environment. The cheese is usually stored under moist and uncontrolled hygienic conditions, which can be contaminated by moulds and yeasts. Therefore, the final flavour and texture will be influenced by the action of the flora.

Recently, the Egyptian organization for standardizadation and quality control published new standards indicating that different cheese varieties must be made from pasteurised milk. These standards aim to produce high quality products for consumer health. This means that cheese makers should use starter cultures in the manufacture of cheese as well as for maintaining the typical flavour of produced cheese. Although, there are several studies on Egyptian Ras cheese, the typical flavour and the flavour volatile compounds of cheese have not been defined.

So the aim of our research work is to identify the typical Ras cheese made from raw milk, so as in further work, to manufacture a typical Ras cheese from pasteurised milk using starter cultures. In our previous study (Awad, El Attar, Ayad, & El-Soda, 2003, part 1), Ras cheese samples tested were characterised by rheological, physico-chemical and microbiological analyses.

The present work focusses on evaluation of the sensory properties and identification of the flavour compounds of Egyptian Ras cheese, made from raw milk.

2. Materials and methods

2.1. Cheese samples

Thirteen samples of commercial Ras cheese, made from raw milk in winter and in spring at different age ripening; 3 and 12 months, were collected from cheese distributors. Cheese samples were manufactured in different rural places located in the delta region: Damnhor, Domietta, Kafer El-sheich, Menoufia, Abo-Homos, Mahmodia, and Alexandria.

2.2. Sensory evaluation

The sensory evaluation was carried out by a panel consisting of 10–30 cheese graders, including staff members and assistants at the University of Alexandria, Dairy science and technology department, cheese producers and cheese consumers. Each panel member assessed the cheeses separately, taking into account the following features: flavour (odour and taste), texture, section and colour. For assessment of flavour, section and colour, the following scale were used: 1, bad; 2, sufficient; 3, good; 4, very good. The scale for texture was: 1, soft/firm; 2, normal; 3, hard; 4, very hard. Intensity of flavour and texture attributes were scored on a scale from 1, slightly; 2, moderate; 3, strong; 4, very strong. A list containing the most widely accepted description of flavour, off-flavours, texture, section and colour of the cheese was present to aid the panellists in carrying out the organoleptic evaluation. Moreover, the graders were asked to give the cheese an overall grade out of (100) and to whether each sample was typical Ras cheese or not and any additional comments. The sensory evaluation procedure was modified from the method described by (Ayad, Verheul, Wouters, & Smit, 2000). The averages of sensory evaluations data with standard deviations were determined.

2.3. Rheological properties

Objective tests for Ras cheese were carried using a texture analyser (CNS-Farnell, England). Cheese samples were cut into cubes (5 cm^3) and kept at 12 °C for 1 h before analysis. The probe was TA 17 (30° and 35 mm diameter), at a speed of 1 mm/s and 10 mm distance, using cycle or normal programmes. Hardness, consistency, cohesiveness, springiness, fracturability, gumminess, modulus and adhesiveness were calculated as described by Szczesniak, Brandt, and Freidman (1963) and Bourne (1978), The analysis were carried out three times and the means of data with standard deviation were determined.

2.4. Analysis of volatile compounds

Volatile compounds of the cheese samples were identified at NIZO Food research in Ede, The Netherlands, using purge-and-trap thermal desorption cold-trap (TDCT) gas chromatography mass spectrometry (GC-MS) (Neeter & De Jong, 1992). Briefly, 20 ml of cheese slurry, obtained by homogenization of a mixture of cheese and double-distilled water (1:2 w/v), was prepared and used immediately after the preparation. The samples were purged with 150 ml min^{-1} helium gas for 30 min at 42 °C and volatile components were trapped on an absorbent trap containing carbotrap (80 mg, 20–40 mesh, Supelco) and carbosieve SIII (10 mg, 60–80 mesh, Supelco). The trapped compounds were transferred onto a capillary column of a gas chromatograph, using the Chrompack PTI injector (Chrompack, The Netherlands) in the TDCT model, by heating the trap for 10 min at 250 °C. A narrow injection band was achieved by cryofocusing at −100 °C. The conditions for the chromatographic separation and mass spectrometry have been used as described by (Engels et al., 1997). Structures of the volatile compounds were assigned by spectrum interpretation, comparison of the spectra with bibliographic data and comparison of retention times with those of reference compounds.

3. Results and discussion

3.1. Sensory evaluation of cheese

Thirteen samples of commercial Ras cheese collected from different places were assessed sensorially (Fig. 1). The average grading scores for flavour, texture, section and colour are presented. The sensory results indicated that four samples were evaluated as not typical of Ras cheese and nine samples were typical.

Not typical samples were numbers 7, 9, 11 and 13, and received low scores (out of 100); 55, 50, 35 and 30, respectively. The samples also received the lowest flavour score (Fig. 1). The flavour of these cheeses is described in general as: unclean, bitter, rancid, flat, mouldy and salty. These flavour attributes are mentioned as off-flavours in cheese (Fox, Singh, & McSweeney, 1995; Law, 1982; Ogden, 1993). The texture of cheese number 7 was (soft/firm) while cheese numbers 11 and 13 were hard and very hard, respectively. On the other hand, sample number 9 had a normal texture. These results are in agreement with reported rheological measurements for cheeses (Awad et al., 2003). The sections of not typical cheese samples were found to have mechanical openings, irregular in shape and with gassy openings. The colour was regular in samples 7, 9 and 13 but speckled in sample number 11.

According to sensory results, nine typical cheese samples can be divided into two groups based on the overall score grade (out of 100), ranging from 60 to 75 for the first group and from 80 to 95 for the second group.

The first group, including cheese numbers (1, 3 and 4), received grades 75, 60 and 70, respectively, with sufficient flavour. The flavours were described as tasty, sharp, old cheese-like and also rancid (slightly) and salty was mentioned for sample number 3. Salty taste corresponds with chemical analysis results since cheese sample 3 has the highest salt content (4.3%). The textures of cheese numbers 3 and 4 were hard while cheese number 1 was very hard. These results resembled the results of rheological measurements. The section of cheeses was described as irregular mechanical openings, and gassy openings. The colour was regular in sample 1, but speckled (slightly) in sample numbers 3 and 4.

The second group including cheese numbers (2, 5, 6, 8, 10 and 12), received the highest overall grades (95, 80, 85, 80, 90 and 80, respectively). The flavour scores were very good in samples 2, 6, 10, 12 and good in cheese samples 5 and 8 (Fig. 1). The flavour attributes of these cheeses are typical of Ras cheese: tasty, good flavour, sharp, piquant, ripened cheese and also fatty (moderate) were mentioned in sample numbers 2, 8 and 10 during the sensory evaluation. Description such as fatty taste agrees with chemical analysis results; cheese samples 2, 8 and 10 have the highest fat contents, i.e., 39.5%, 39% and 38.1%. Sample number 12, which is 3-months-old cheese, was evaluated as a typical Ras cheese as were other samples which were 12-months-old. Ras cheese is normally marketed when it has a sharp flavour close to that of Kefalotyri cheese (Scott, 1981) that may start after three or four months of ripening. The texture of all cheeses in this group is normal. The sections of cheese numbers 2, 6, 10 and 12 were very good and cheese samples 5 and 8 were good. Irregular mechanical

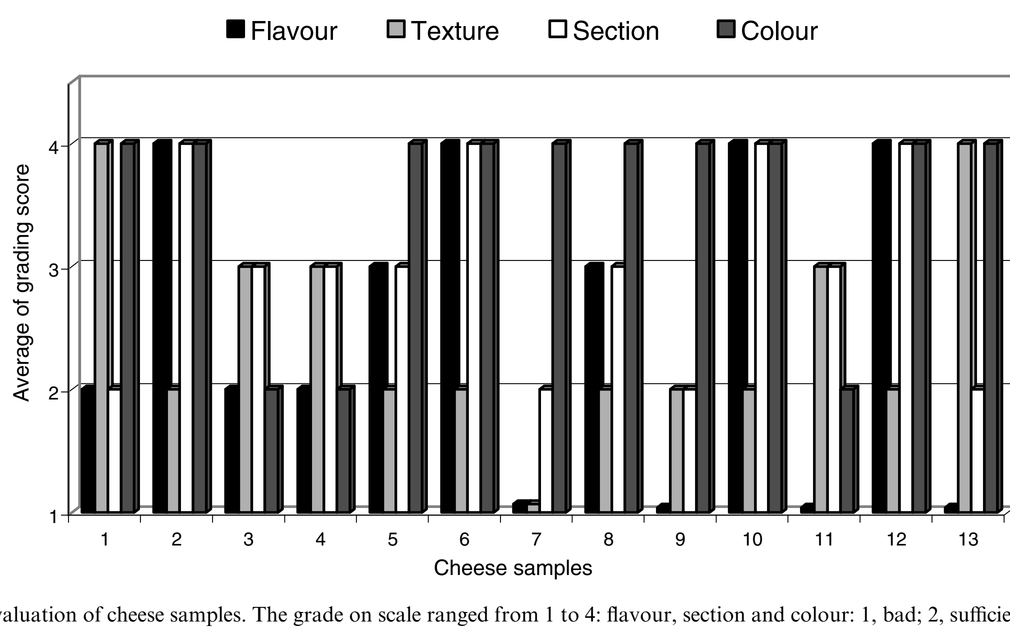

Fig. 1. Sensory evaluation of cheese samples. The grade on scale ranged from 1 to 4: flavour, section and colour: 1, bad; 2, sufficient; 3, good; 4, very good; texture: 1, soft/firm; 2, normal; 3, hard; 4, very hard. The results are means with standard deviation ranged from 0.1 to 0.5.

Table 1
Sensory evaluation of cheese

Cheese numbers	Flavour (smell and taste)		Texture (consistency)		Section		Colour		Comments
	Grade[a]	Description (intensity)[b]	Grade[c]	Description (intensity)	Grade[a]	Description (intensity)	Grade[a]	Description (intensity)	
2	4 ± 0.3	Tasty (3), typical flavour (3), oily	2 ± 0.2	Normal	4 ± 0.1	Mechanical opening (2), gassy opening (1)	4 ± 0.3	Regular colour (4)	Typical Ras cheese 95[d] ± 4.6
10	4 ± 0.4	Sharp (2), tasty (3), fatty (2), piquant (2)	2 ± 0.3	Normal	4 ± 0.4	Mechanical opening (1), gassy opening (2)	4 ± 0.5	Regular colour (4)	Typical Ras cheese 90 ± 3.9
11	1 ± 0.2	Bitter (2), unclean flavour (2)	3 ± 0.4	Hard (2)	3 ± 0.3	Mechanical opening (1), gassy opening (3)	2 ± 0.5	Spekled colour (2)	Not Typical Ras cheese 40 ± 5.71
12	3 ± 0.2	New (not old), good flavour	2 ± 0.2	Normal	4 ± 0.3	Mechanical opening (1), gassy opening (2)	4 ± 0.2	Regular colour (4)	Typical Ras cheese 80 ± 6.6

The results are means with standard deviations.
[a] Grade on scale from 1 to 4: 1, bad; 2, sufficient; 3, good; 4, very good.
[b] Intensity remarks on scale from 1 to 4: 1, slightly; 2, moderate; 3, strong; 4, very strong.
[c] Grade on scale from 1 to 4: 1, soft/firm; 2, normal; 3, hard; 4, very hard.
[d] Overall grade out of (100).

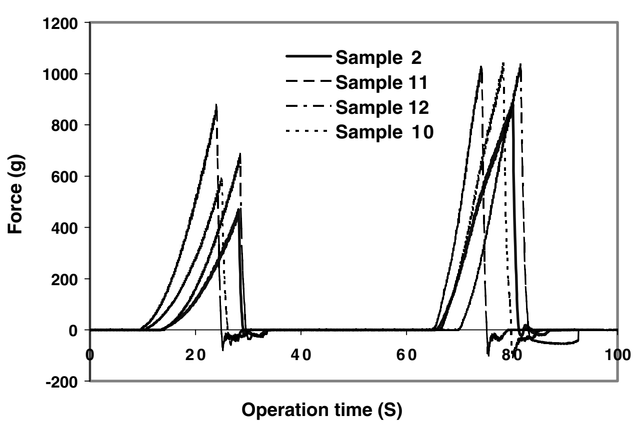

Fig. 2. Typical cycle penetration curve of Ras cheese samples 2, 10, 11 and 12.

openings were found in the sections of cheese samples and also gassy openings in sample numbers 10 and 12. The colour was described as regular in all samples.

However, the mechanical openings were noted in all cheese samples, either typical or not typical. That is normal in this kind of hard cheese (Egyptian Standards, 2001), and results from the press step during cheese manufacturing (Hofi et al., 1970). Gassy opening in cheese is known to be caused by growth of gas-producing organisms *Lactococcus lactis* sp. *lactis* biovar. *diacetylactis* or *leconostoc* sp., obligatory heterofermentative lactobacilli and coliforms (Limsowtin, Powell, & Parente, 1996; Ogden, 1993). In Ras cheese, made from raw milk, gassy opening results from ''coliforms'' which can be introduced into the cheese by unsanitary practices and

Table 2
The rheological properties of Ras cheese

	Cheese samples			
	2	10	11	12
Hardness (g)	472 ± 21	647 ± 29	869 ± 38	685 ± 19
Consistency (g s^{-1})	2495.5 ± 51	3289 ± 43	4645 ± 39	3358 ± 47
Adhesiveness (g s^{-1})	−67.2 ± 3.4	−19.0 ± 2.5	−26 ± 3.5	−34 ± 2.0
Moduls (g s^{-1})	32.6 ± 2.4	45.4 ± 3.4	57. 8 ± 4.8	46.4 ± 2.6
Fracturability (g)	470 ± 20	647 ± 28	794 ± 35	667 ± 19
Cohesiveness (ratio)	0.38	0.76	0.98	0.84
Springiness (mm)	7.42 ± 0.9	5.54 ± 0.6	4.89 ± 0.4	5.71 ± 0.6
Chewiness (g mm^{-1})	1330.85	2724.13	4164.42	3285.53

The results are means with standard deviations.

Table 3
GC-MS analysis of volatile compounds in Egyptian Ras cheese

Compounds	Relative peak area[a]			
		Cheese sample		
	Sample 2	Sample 10	Sample 11	Sample 12
Alcohols				
Methanol	607	296	140	283
Ethanol	199	377	**1754**[b]	919
2-Propanol	72	66	7	157
1-Propanol	145	180	**319**	128
2-Butanol	1391	633	238	**6152**
2-Methylpropanol	21	0	0	**158**
1-Butanol	**1387**	528	438	841
2-Pentanol	**6529**	0	426	586
3-Methylbutanol	885	775	**2785**	**1154**
2-Methylbutanol	712	661	**1339**	911
1-pentanol	929	2956	0	826
1-Hexanol	335	0	247	86
Heptanol-1	350	258	**838**	23
Aldehydes				
Aceetaldehyde	**1049**	631	508	718
Propanal	339	**592**	51	137
2-Methylpropanal	7	5	14	27
2-Butenal	4	4	8	13
Butanal	**354**	229	59	10
3-Methylbutanal	10	8	25	**143**
Pentanal	**884**	**866**	230	0
Hexanal	187	**868**	0	49
Benzaldehyde	65	20	**2429**	82
Nonanal	18	6	5	29
Decanal	5	3	0	24
Ketones				
Acetone	295	153	294	824
Dimethylsulfone	2	1	1	3
Diacetyl	493	71	279	**1362**
Butanone-2	189	116	77	1302
Pentanone-2	11849	9429	2646	8732
2,3-Pentanedione	469	269	28	271
3-Penten-2-one	48	39	6	46
3-Methyl-2-pentanone	200	71	29	191
5-Hexen-2-one	22	15	0	34
2,3-Hexanedione	17	14	2	2
Hexanone-2	770	508	32	67
Heptanone-2	**5307**	**3918**	459	556
3,5-octadien-2-one	0	5	**26**	3
8-Nonen-2-one	679	**866**	0	16
Nonanone-2	987	**1004**	41	33
Undecanone-2	2	1	0	1
Tridecanone-2	2	1	1	3
Esters				
Ethylacetate	31	34	122	132
Ethylpropionate	65	273	**5997**	499
Propylacetate	874	1182	**3532**	499
Methylpropylacetate	**209**	154	88	92
Ethylbutanoate	2639	2775	**12672**	2433
Butylacetate	183	115	245	23
Propylpropionate	126	197	**2887**	63
1-Methylethylbutanoate	19	11	5	2
3-Methyl-2-butanolacetate	307	237	23	13
2-Methylethylbutanoate	43	37	**105**	22
3-Methylethylbutanoate	138	138	163	72
3-Methyl-1-butanolacetate	151	87	163	136
Propylbutanoate	2439	1835	**7598**	299

Table 3 (*continued*)

Compounds	Relative peak area[a]			
		Cheese sample		
	Sample 2	Sample 10	Sample 11	Sample 12
Ethylpentanoate	162	130	**1271**	103
Methylhexanoate	385	300	57	75
Methylpropylbutanoate	498	201	271	57
Ethylhexanoate	6270	5075	**22673**	**56073**
2-Methyl-3-methylbutylpropionate	9	5	2	1
3-Methylbutylbutanoate	18	10	42	7
Ethylheptanoate	681	409	**1486**	20
Ethyloctanoate	256	229	**2954**	217
Propyloctanoate	7	3	**17**	1
Ethyldecanoate	6	5	**254**	9
Other compounds				
Methylmercaptan	6	5	19	8
2-Ethylfuran	60	168	**391**	71
2,6-Dimethylpyrazine	88	40	**466**	13
Limonene	95	11	7	22

Relative high concentration are indicated in bold.
[a] The numbers of the volatile compounds related to the retention time.
[b] Relative peak areas of the identified peaks.

contamination. For instance, in cheese numbers 10 and 11 (12-months-old cheese), the colony forming units of coliforms were 10^5 whereas the coliform count in cheese number 12 (3-months-old cheese) was higher. This means that all cheese samples contained coliforms but the viability of coliforms decreased during ripening. However, the gassy opening is an undesired characteristic of Ras cheese (Egyptian Standards, 2001).

As an example, the results of sensory evaluation of four cheeses (three are evaluated as typical cheese, numbers 2, 10, 12 and, as not typical, cheese number 11) are shown in Table 1. These four cheeses were selected for further study of the rheological properties and for identification of flavour compounds by GC-MS.

3.2. Rheological properties

The rheological properties of Ras cheese numbers 2, 10, 11 and 12 were determined using a texture analyser (CNS-Farnell, England). A typical load/penetration curve of cheeses is shown in Fig. 2 and the break point and hardness were obtained from the curves. The rheological parameters (hardness, consistency, adhesiveness, modulus, fracturability, cohesiveness, springiness and chewiness) were calculated as described by Szczesniak et al. (1963) and Bourne (1978) and the data are presented in Table 2. The results showed that the hardness and consistency of cheese sample number 11 were higher than those of other samples. A positive relationship was found between the hardness, consistency and dry matter (Awad et al., 2003, part 1). Dry matter (DM%) of sample 11 was 68.8 whereas DM% of samples 2, 10 and 12 were 66.08, 66.3 and 65.8, respectively. A good correlation was also found between the hardness and consistency calculated by machine and the texture score evaluated by panellists (Fig. 1 and Table 1), whereas, a negative relationship was found between hardness and adhesiveness, springiness and hardness of samples. A positive relationship was found between hardness and modulus, hardness and cohesiveness and also between consistency and chewiness. The fracturability of cheese samples was related to hardness and had almost the same value as hardness (Table 2). The rheological properties of all tested Ras cheeses were discussed in detail (Awad et al., 2003, part 1) and the definitions of all of these parameters are reviewed by Fox, Guinee, Cogan, and McSweeney (2000).

3.3. Volatile compounds of Ras cheese

The volatile compounds produced in four Ras cheeses, as examples, were identified using purge-and-trap TDCT GC-MS. The cheese numbers 2, 10, 11, and 12 were selected for GCMS analysis, based on sensory evaluation as typical Ras cheese (numbers 2, 10 and 12) and not typical (number 11) and also on the ripening times of the cheeses; 3-months-old (number 12) and 12-months-old (numbers 2, 10 and 11). Many different compounds were detected and characterized in the cheeses. The volatile compounds produced in cheeses are listed in Table 3 and the GC-MS aroma profiles of cheeses are presented in Fig. 3. Sixty-eight volatile compounds were identified in Ras cheese samples; these included 13 alcohols, 11 aldehydes, 17 ketones, 25 esters and 4 other compounds (Table 3).

Typical Ras cheese samples 2 and 10 (12-months-old cheeses) had almost the same volatile compounds; with exceptions, 3 alcohols (2-methylpropanol, 2-pentanol

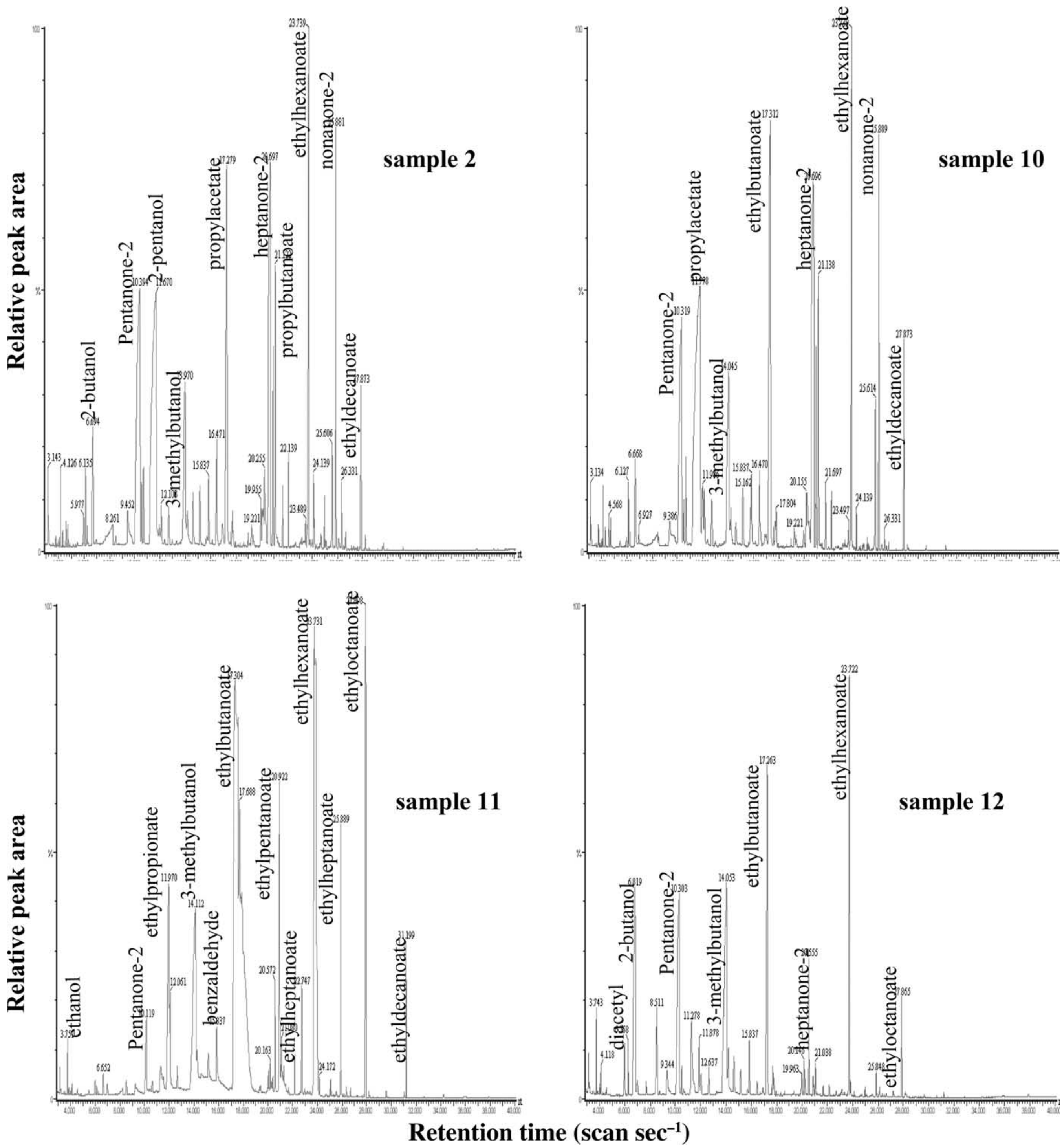

Fig. 3. GC-MS aroma profiles of volatile compounds purged from Ras cheese.

and 1-hexanol) were not detected in sample number 10 (see Table 3). Cheese number 2 was found to contain more aldehydes (acetaldehyde, propanal, butanal, pentanal), ketones (3-methyl-2-pentanone, pentanone-2, hexanone-2, heptanone-2, 8-nonen-2-one, nonanone-2) and some other components (1-butanol, 2-pentanol, limonene, 3-methyl-2-butanolacetate, methylhexanoate, methylpropylacetate and methypropylbutanoate). Cheese number 10 had high levels of aldehydes (propanal, butanal, pentanal, hexanal), ketones (pentanone-2, hexanone-2, heptanone-2, 8-nonen-2-one, nonanone-2) and some other components (3-methyl-2-butanolacetate, methylhexanoate and methylpropylacetate). The differences in the flavour volatile compounds detected in the two cheeses might be due to the manufacture of the two cheeses in different places (Damnhor and Mahmodia), from different raw milks and subsequently different microorganisms. Typical Ras cheese number 12 (3-months-old) contained the same volatile compounds as cheese numbers 2 and 10 but some compounds were in low concentration, e.g., 2 aldehyde, 4 ketones, 8 esters and 2,6-dimethylpyrazine (Table 3). However, this cheese contained more diacetyl, butanone-2, 2-butanol, ethylacetate, 2-methylpropanol, 3-methylbutanal, 3-methylbutanol, 2-methylbutanol, 3-methyl-2-pentanone and ethylhexanoate. These compounds may be reduced during cheese ripening.

Not typical Ras cheese number 11 had higher levels of ethylesters (ethylpropionate, ethylbutanoate, 2-methylethylbutanoate, ethylpentanoate, ethylhexanoate, ethylheptanoate, ethyloctanoate), some other esters (propylacetate, butylacetate, propylpropanoate, propylbutanoate) and some other components (methylmercaptan, 2-ethylfuran, 3-methylbutanol, 2-methylbutanol, heptanol, 2,6-dimethylpyrazine and benzaldehyde), than other samples. Six volatile compounds were not detected in this cheese (2 alcohols, 2 aldehydes and 3 ketones). All of these aroma-compounds, found in high levels and also undetected compounds may play a role in the not typical flavour description of cheese number 11. As reported previously, cheese ripening involves a complex series of consecutive microbiological, biochemical and chemical events which, if synchronised and balanced, lead to products with desirable flavour but when unbalanced, result in off-flavour. For instance, when ethyl-butyrate is present at high concentrations in cheese, a flavour defect occurs due to excessive production of ethanol (Fox et al., 1995). This is found in cheese sample number 11 with a high level of ethanol. Dunn and Lindsay (1985) also found that, when branched chain aldehydes and corresponding alcohols, are present at high concentration in Cheddar cheese, this causes a flavour defect (unclean flavour). This defect was noted during sensory evaluation of this cheese, which had high levels of the branched chain alcohols 2- and 3-methylbutanol. However, this unclean defect may also come from poor quality milk used for cheese manufacture (Ogden, 1993).

The quality of matured cheese, manufactured under artisanal production, from raw milk without using starter cultures, is influenced by wild microflora (natural milk cultures) that include mesophilic and thermophilic LAB, enterococci and also coliform bacteria and yeasts, sometimes present if the production is under poor hiegenic conditions (Ottogalli & Galli, 1967). Four tested cheese samples 2, 10, 11 and 12 contained LAB, coliforms, staphylococci, yeasts and moulds (Awad et al., 2003, part 1). The flavour-forming abilities depend on the enzymes present, so different flavours can be obtained (Manning, 1979; Olson, 1990). Therefore, the flavour of Ras cheese in the present work results from the interaction of enzymes from the microorganisms.

Alcohols and aldehydes detected in cheese result from catabolism of amino acids (Hemme, Bouillanne, Metro, & Desmazeaud, 1982). The concentrations of the different ketones varied between the different cheese samples. Methyl-ketones, which are well known for their contribution to the flavour of blue mould-ripened cheeses, are formed by enzymic oxidative decarboxylation of fatty acids, by the action of mould (Kinsella & Hwang, 1976). Diacetyl, found in high level in sample number 12, is known to come from citrate conversion and is responsible for a creamy flavour (Welsh, Murray, & Williams, 1989). Some differences in the levels of ethyl-esters were also encountred between cheeses. These compounds are formed by enzymic or chemical reactions of fatty acids with primary alcohols, as reported by Barbieri et al. (1994). However, esters when found in Cheddar cheese, are regarded as a defect (fruity flavour) whereas, they are important contributors to the flavour of Parmesan cheese (Meinhart & Schreier, 1986; Urbach, 1997).

4. Conclusion

The typical Ras cheese, favoured by Egyptian consumers, is tasty, sharp and piquant in flavour, not too hard and not soft in texture and the body includes some mechanical openings, with few gassy openings and the colour is regular. Sixty-eight volatile compounds were identified in Ras cheese samples, including alcohols, aldehydes, ketones, esters and other compounds, which are responsible for the typical flavour. There were difference in the concentrations of these aroma-compounds corresponding with the ages of cheeses and their sensory evaluation.

References

Adda, J. (1986). Flavours of dairy products. In G. G. Birch & M. G. Lindley (Eds.), *Developments in food flavours* (pp. 151–172). London: Elsevier Applied Science.

Awad, S., El Attar, A., Ayad, E. H. E., & El-Soda, M. (2003). Characterisation of Egyptian Ras cheese. 1. Sensory evaluation, rheological, physico-chemical properties and microbiological analysis. *Egyptian Journal of Dairy Science, 31*, 289–303.

Ayad, E. H. E., Verheul, A., Wouters, J. T. M., & Smit, G. (2000). Application of wild starter cultures for flavour development in pilot plant cheese making. *International Dairy Journal, 10*, 169–179.

Barbieri, G., Bolzoni, I., Careri, M., Manglia, A., Parolari, G., Spagonoli, S., & Virgili, R. (1994). Study of the volatile fraction of parmesan cheese. *Journal of Agricultural and Food Chemistry, 42*, 1170–1176.

Bosset, J. O., & Gauch, G. (1993). Comparison of the volatile flavour compounds of six European 'AOC' cheeses using a new dynamic headspace GC-MS method. *International Dairy Journal, 3*, 423–460.

Bourne, M. (1978). Texture Profile Analysis. *Food Technology, 32*(7), 62–66,72.

Broome, M. C., & Limsowtin, G. K. Y. (1998). Starter peptidase activity in maturing cheese. *Australian Journal of Dairy Technology, 53*, 79–82.

Code of Fedral Regulations (1990). Title 21. Part 133. Cheese and related cheese products. Washington, DC: U.S. Government Printing Office.

Crow, V. L., Coolbear, T., Holland, R., Pritchard, G. G., & Martley, F. G. (1993). Starters as finishers: Starter properties relevant to cheese ripening. *International Dairy Journal, 3*, 423–460.

Delahunty, C. M., & Piggott, J. R. (1995). Current methods to evaluate contribution and interactions of components to flavour of solid foods using hard cheese as an example. *International Journal of Food Science and Technology, 30*, 555–570.

Dunn, H. C., & Lindsay, R. C. (1985). Evaluation of the role of microbial Strecker-derived aroma compounds in unclean-type flavours of Cheddar cheese. *Journal of Dairy Journal, 68*, 2859–2874.

Egyptian standards for hard cheese (2001). Part 5: Ras cheese, ES: 1007/2001. Ministry of Industry and Technological Development, Egypt.

Engels, W. J. M., Dekker, R., De Jong, C., Neeter, R., & Visser, S. (1997). A comparative study of volatile compounds in water-soluble fraction of various types of ripened cheese. *International Dairy Journal, 7*, 255–263.

Fox, P. F., Guinee, T. P., Cogan, T. M., & McSweeney, P. L. H. (2000). *Fundamental of cheese science. Cheese rheology and texture* (pp. 298-340). Jaithers Burg, MD: Aspen Publisher Inc.

Fox, P. F., O'Connor, T. P., McSweeney, P. L. H., Guinee, T. P., & O'Brien, N. M. (1996). Cheese: Physical, biochemical and nutritional aspects. *Advances in Food and Nutrition Research, 39*, 163–305.

Fox, P. F., Singh, T. K., & McSweeney, P. L. H. (1995). Biogenesis of flavour compounds in cheese. In E. L. Malin & M. H. Tunick (Eds.), *Chemistry of structure/function relationships in cheese* (pp. 59–98). New York: Plenum.

Hemme, D., Bouillanne, C., Metro, F., & Desmazeaud, M. J. (1982). Microbial catabolism of amino acids during cheese ripening. *Science Alimentra, 2*, 113–123.

Hofi, A. A., Yossef, E. H., Ghoneim, M. A., & Tawab, G. A. (1970). Ripening changes in Cephalotyre "Ras" cheese manufactured from raw and pasteurized milk with special reference to flavour. *Journal of Dairy Science, 53*, 1207–1212.

Kinsella, J. E., & Hwang, D. H. (1976). Enzymes of *Penoicillium roqueforti* involved in the biosynthesis of cheese flavour. *Critical Reviews in Food Science and Nutition*, 8191–8228.

Law, B.A. (1982). Cheeses. In A. H. Rose (Ed.), *Economic microbiology: Fermented foods* (Vol. 7, p. 147). London: Academic Press.

Limsowtin, G. K. Y., Powell, I. B., & Parente, E. (1996). Types of Starters. In T. M. Cogan & J.-P. Accolas (Eds.), *Dairy starter cultures* (pp. 101–129). New York: VCH.

Maarse, H., & Visscher, C. A. (1989). *Volatile compounds in foods: Qualitative and quantitative data* (p. 49). The Netherlands: Zeist, TNO-CIVO, Food Analysis Institute.

Manning, D. J. (1979). Chmical production of essential Cheddar flavour compounds. *Journal of Dairy Research, 46*, 531–537.

Meinhart, E., & Schreier, P. (1986). Study of flavour compounds from Parmigiano Reggiano cheese. *Milch-wissenschaft, 41*, 689–691.

Neeter, R., & De Jong, C. (1992). Flavour research on milk product: Use of purge-and-trap techniques. *Voedingsmiddelentechnologie, 25*, 9–11.

Nijssen, L., Visscher, C. A., Maarse, H., Willemsens, L. C., & Boelens, M. H. (1996). *Volatile compounds in food*. Zeist, Netherlands: TNO.

Ogden, L. V. (1993). Sensory evaluation of dairy products. In Y. H. Hui (Ed.), *Dairy science and technology hand book. 1. Principles and properties* (pp. 157–276). New York: VCH.

Olson, N. F. (1990). The impact of lactic acid bacteria on cheese flavor. *FEMS Microbiological Review, 87*, 131–148.

Ottogalli, G., & Galli, A. (1967). Natural milk cultures used for the manufacture of the Crescenza variety. *Annali di Microbiologia, 17*, 191–197.

Scott, R. (1981). *Cheesemaking practise* (1st ed., p. 441). London: Applied Science Publishers Ltd.

Szczesniak, A., Brandt, M., & Freidman, H. (1963). Development of Standard Rating Scales for Mechanical Parameters and Correlation Between the Objective and Sensory Texture Measurements. *Food Technology, 22*, 50–54.

Urbach, G. (1995). Contribution of lactic acid bacteria to flavour compound formation in dairy products. *International Dairy Journal, 5*, 877–903.

Urbach, G. (1997). The flavour of milk and dairy products in cheese: Contribution of volatile compounds. *International Journal of Dairy Technology, 50*, 79–89.

Welsh, F. W., Murray, W. D., & Williams, R. E. (1989). Microbiological and enzymatic production of flavor and fragrance chemicals. *CRC Critical Reviews in Biotechnology, 9*, 105–169.