Comparative Analysis of Rapeseed Oils Prepared by Three Different Methods

Qiaona Yuan, Mengjie Tu, Pan Gao *, Chuanrong Hu, and Dongping He

Key Laboratory for Deep Processing of Major Grain and Oil (Wuhan Polytechnic University) of Ministry of Education in China, College of Food Science and Engineering, Wuhan Polytechnic University, Wuhan, 430023, P.R. CHINA

Abstract: Flavoured rapeseed oils prepared using traditional technologies (oils A and B) and a fragrant rapeseed oil obtained using an enzymatic Maillard reaction (oil C) were analysed to show that oil C featured basic indicators and a fatty acid composition similar to those of traditional oils while exhibiting a higher comprehensive sensory evaluation score. Volatile component, odour activity value (OAV), and relative odour activity value (ROAV) analyses revealed that oil C had an elevated content of pyrazines (20.83%) and aldehydes (38.15%), which resulted in stronger charred and caramel flavours. The aroma of oil C was directly impacted by 3-methylbutyraldehyde (OAV > 1) and was modified by 3-methylthiopropionaldehyde and nonanal (ROAV > 1 in both cases). Thus, the developed technology was found to be well suited for the production of novel and safe fragrant rapeseed oil.

Key words: flavoured rapeseed oil, Maillard reaction, relative odour activity value, sensory evaluation, 3-methylbutyraldehyde

1 Introduction

Rapeseed oil is one of the most commonly produced edible oils1, featuring a well-balanced proportion of linoleic (C18:2) and linolenic (C18:3) acids, the first of which exhibits important physiological and health-promoting effects, especially toward prevention of allergies and inflammatory/cardiovascular diseases2. As oil a strong fragrance is more popular than unscented oil, fragrant rapeseed oil has garnered increasing attention.

Fragrant oils are produced by (filter-)pressing, water replacement, extraction and other methods. In particular, the technology of fragrant rapeseed oil production has developed from whole-seed pressing through peel-pressing to roasted seed pressing. Fragrant rapeseed oil produced by traditional pre-pressing-extraction or roasting-pressing may contain benzopyrene (BaP), which is formed at high temperatures3 and is a well-known chemical contaminant with potential carcinogenic effects4. In addition, traditional methods of rapeseed oil production are complicated and afford oils with unstable quality, e.g. oil flavoured is affected by rapeseed variety, moisture content, and steaming temperature/time. Depending on its flavoured, fragrant rapeseed oil can be described in a number of ways, e.g. as having a strong/mellow/clear fragrance or as small squeezed pure. In recent years, fragrant oils have been increasingly frequently produced by the Maillard reaction, which is a reaction that occurs between reducing sugars and compounds containing amino and carbonyl groups5, and have a unique flavoured7, smooth taste, and a high nutritional value8. However, the related fragrant oil production processes are complex and difficult to control.

Herein, we develop a new Maillard-reaction-based technology of preparing safe and stable-quality fragrant rapeseed oil and compare it with traditional methods used to produce oil; identify oil volatile (flavoured) components and their relative contents; and use the concept of relative activity to determine the components that most significantly contribute to oil flavoured.

2 Materials and Methods

2.1 Materials

Rapeseed was supplied by Chengdu Xinxing Grain and

Abbreviations: OAV, odour activity value, ROAV, relative odour activity value, AV, acid value, BaP, benzopyrene, AFB1, aflatoxin B1, POV, peroxide value, IV, iodine value, OSI, oxidation stability index, DMF, dimethylformamide, SPE, solid-phase extraction, HPLC-FLD, high performance liquid chromatography-fluorescence detector, SPME, solid phase microextraction, PUFA, polyunsaturated fatty acid, USFA, unsaturated fatty acid.
Oil Co., Ltd (Sichuan, China), and rapeseed cake was obtained after the cold pressing of rapeseed oil from the same seeds. Alkaline protease (200,000 U/g), neutral protease (200,000 U/g), papain (10,000 U/g), and flavoured protease (15,000 U/g) were supplied by Jiangsu Ruiyang Biotechnology Co., Ltd. (Jiangsu, China). Phthalate standards were purchased from Sigma-Aldrich Chemical Co. Ltd. (Shanghai, China). Aflatoxin B1 (AFB1) Quick Pick Kit was obtained from Shanghai Enzyme Biotechnology Co., Ltd. (Shanghai, China). Other reagents and solvents were purchased from Sinopharm Chemical Reagent (Shanghai, China).

2.2 Sensory evaluation system

The panel constituted of twelve professionals (10 women and 2 men) of the Food Institute of the Wuhan Polytechnic University. The panellists were selected to form a sensory evaluation board. Oil samples (20 mL) were kept in 50 mL closed beakers. Each panellist received five oil samples and sequentially evaluated their rapeseed flavoured, charred flavoured, caramel flavoured, flavoured persistence, and comprehensive score. The final comprehensive score was calculated using principal component analysis to determine the proportions of the four above components.

2.3 Rapeseed oil preparation

2.3.1 Rapeseed oil A

Rapeseed was ground, steamed at 140–150°C in a steamer (MA-SHY28-2A, Guangdong Midea Life Electrical Manufacturing Co., Ltd, China), pressed, and centrifuged for 10 min at 4,000×g to produce rapeseed oil A as the supernatant.

2.3.2 Rapeseed oil B

Rapeseed was steamed (MA-SHY28-2A) and pressed as described for rapeseed oil A. Subsequently, distilled water (15 wt%) was added, and the mixture was stirred at maximum speed for 15 min, degummed, and centrifuged at 4,000×g for 10 min. The supernatant was dried in vacuum oven at 50°C, and the oil was cooled to 25°C to yield rapeseed oil B (Fig. 1B).

2.3.3 Rapeseed oil C

The rapeseed cake (60 g) was crushed, sieved, roasted at 135°C for 5 min, cooled to 25°C, and mixed with distilled water (180 mL). The resulting mixture was supplemented with fructose (1.2 g) and magnetically stirred at 25°C. Subsequently, pH was adjusted to 9 using 0.2 M aqueous NaOH, the solution was supplemented with alkaline protease (4.0 g) and flavoured protease (2.0 g), and the vessel was sealed with a plastic wrap. The mixture was shaken in an air-bath thermostat at 200–900 rpm and 50°C, and pH was adjusted to 9 every 1 h. After shaking, the hydrolysate was centrifuged. The supernatant (30 g) and residue (18 g) obtained from the enzymatic hydrolysis after centrifugation were treated, and 150 g of refined rapeseed oil was added. The resulting mixture was heated for 20–45 min in an oil bath at a constant temperature of 130°C upon magnetic stirring, with the rotation speed set in such a way as to avoid liquid overflow. Subsequently, the mixture was centrifuged, and the supernatant was filtered to yield fragrant rapeseed oil C (Fig. 1C).

2.4 Basic indicators

The acid value (AV), peroxide value (POV), and iodine value (IV) were determined using ISO 660, ISO 3960, and ISO 3961 methods, while the smoke point was determined according to AOCS.

2.5 Oxidation stability index (OSI)

The continuous bubbling of air at a flow rate of 20 L/h through the oil samples (3.0 g) held at 140°C was used to
measure OSI, which was expressed in hours\textsuperscript{[14]}.

### 2.6 Fatty acid composition

Typically, an oil sample (\textasciitilde 100 mg) was saponified with aqueous KOH (2 M, 100 mL) and supplemented with \textit{n}-hexane (5 mL). The mixture was vigorously shaken using a Vortex mixer for 1 min, and then centrifuged at 5,000 \textit{x} g for 5 min. The resulting supernatant (1 mL) was used for fatty acid analysis, which was performed using a 6890N gas chromatograph (Agilent, USA) equipped with a Supelco HP 88 capillary column (0.2 \textmu m, 100 \times 0.25 mm) and a flame ionisation detector. Hydrogen was used as a carrier gas at a flow rate of 1.3 mL/min, the split ratio was 1/50, the injection volume was 1 \mu L, and the injection temperature was set to 250°C. The initial column temperature of 130°C was held for 1 min, increased at 6.5°C/min to 170°C, further increased at 2.75°C/min to 215°C and maintained for 12 min, and finally increased to 230°C at 5°C/min, and maintained for 5 min\textsuperscript{[5]}. Fatty acids were identified by comparing their retention times with those of standards, and fatty acid content was expressed as the percentage of total fatty acid weight. Each sample was analysed in triplicate.

### 2.7 BaP and aflatoxin contents

Rapeseed oil (1.0 g) was diluted with \textit{n}-hexane (5 mL) and extracted twice with a DMF/water mixture (5 mL; 9:1, \textit{v/v}). The solid-phase extraction column, prepared by packing 0.2 g of spherical SiO\textsubscript{2}-OCA into a polystyrene cartridge, was activated with methanol (5 mL) and DMF/water (5 mL; 1:2, \textit{v/v}). Then, the sample was loaded, and the column was flushed with DMF/water (5 mL) and distilled water (2 mL) and dried. Subsequently, BaP was eluted with dichloromethane (1.5 mL); the extract was evaporated to dryness; and the residue was dissolved in the mobile phase (0.2 mL; acetonitrile/water, 90:10, \textit{v/v}). The solution was filtered through a 0.22 \textmu m nylon membrane and subjected to high performance liquid chromatography-fluorescence detection (HPLC-FLD\textsuperscript{[15]}). HPLC separation was accomplished on a Thermo Hypersil ODS column (5 \mu m, 250 \times 4.6 mm) held at 30°C using an acetonitrile/water (90:10, \textit{v/v}) mixture as the mobile phase at a flow rate of 1 mL/min. The excitation and emission wavelengths equaled 255 and 420 nm, respectively, and the analysis time was 12 min.

An oil sample (5.0 g) was transferred into a 125 mL separatory funnel with \textit{n}-hexane (20 mL) using a disposable syringe, treated with a methanol/water solution (25 mL; 70:30, \textit{v/v}), and shaken for 5 min. After phase separation, the aqueous layer was collected, diluted with an equal volume of distilled water, and a 50 \mu L aliquot of the diluted solution was sampled for AFB\textsubscript{1} determination according to the instructions of the ELISA Quick Pick Kit. After completion of the ELISA test, the reaction was stopped by the addition of the stop reagent, and absorbance at 450 nm was measured to determine AFB\textsubscript{1} content\textsuperscript{[16]}.

### 2.8 Odour activity value (OAV)

OAV, calculated by dividing the concentrations of the compounds with a given aroma by its sensory thresholds obtained from literature, was used to quantify the contribution of the compound to the overall oil aroma, and was positively correlated with this contribution. Only compounds with OAV > 1 were considered to individually contribute to the oil aroma. The greater the OAV value within a certain range, the greater the contribution of this component to the overall odour\textsuperscript{[17]}.

\[
OAV = C / OT_i
\]

where \(C_i\) is the concentration of a given volatile compound in the sample, and \(OT_i\) is the corresponding odour threshold in water (ppb).

### 2.9 Relative odour activity value (ROAV)

ROAV, previously used to identify the key odour compounds of foods, was herein employed to evaluate the contribution of individual compounds to overall oil aroma and identify key odour compounds\textsuperscript{[17]}.

\[
ROAV = 100 \times \frac{C_i/OT_i}{C_{max}/OT_{max}}
\]

where \(C_i\) is the concentration of a given volatile compound in the sample, \(C_{max}\) is the highest concentration of a given volatile compound in the sample, \(OT_i\) is the corresponding odour threshold in water (ppb), and \(OT_{max}\) is the highest corresponding odour threshold in water (ppb).

ROAV ranged from 0 to 100% and was directly proportional to the contribution of a given substance to oil flavoured. Species with ROAV = 100% were considered key odour compounds, while those with ROAV \geq 1% were considered to be important modifiers of sample odour and synergistic effect providers.

### 2.10 Volatile components

The volatile components of rapeseed oils were investigated by headspace solid-phase microextraction (HS-SPME) combined with gas chromatography-mass spectrometry (GC 6890/MS 5975, Agilent, USA). Typically, a 15-mL headspace vial was charged with a rapeseed oil sample (5.0 g) and sealed with a polytetrafluoroethylene (PTFE)-faced silicone septum. Then, SPME fibre was exposed to the headspace and the sample was maintained at 50°C for 30 min. The fibre with adsorbed sample compounds was immediately transferred to the injection port of the gas chromatograph. A time period of 3 min was adopted for desorption.

The volatiles were separated on a DB-WAX capillary column (0.25 \mu m, 30.0 m \times 250 \mu m, Supelco, USA), and the sample was injected in splitless mode. Helium was used as a carrier gas at a flow rate of 0.8 mL/min. The temperature was programmed to increase from 40 (3 min) to 90°C at a rate of 5°C/min, then to 230°C at a rate of 10°C/min, and
hold for 7 min. The injector and detector temperatures were set to 250°C. Mass spectra were recorded using a mass-selective detector in the EI mode, with an electron energy of 70 eV and a scanning mass range of 33–450 m/z. The interface and source temperatures equalled 250 and 200°C, respectively.  

2.11 Statistical analysis  
All data were obtained from duplicates and reported as mean ± standard deviation. Differences in means were statistically analysed by two-way analysis of variance (ANOVA) and Duncan’s multiple range test.

3 Results and Discussion  
3.1 Basic indicators and fatty acid composition  
Figure 2 presents the AV, POV, IV, OSI, smoke point, and BaP contents of rapeseed oils, showing that AV and POV ranged from 1.2 to 1.55 mg/g and from 6.30 to 7.49 mmol/kg, respectively. There was no significant difference between samples, and all samples met the Chinese standard for flavoured rapeseed oil (AV ≤ 2.5 mg/g and POV ≤ 7.88 mmol/kg). IV, which indicates the unsaturation degree of organic compounds, was not significantly different between samples, which confirmed that the investigated oils had stable quality. OSI equalled 1.91–4.45 h, and a significant difference was observed between oils A and B, which was ascribed to the effect of processing method, i.e. unlike oil A, oil B underwent degumming. This result was in line with that of Mao et al., who revealed that degumming can significantly increase the oxidation stability of rapeseed oil. The smoke point refers to the onset of thermal decomposition (which affords products, that can be continuously volatilised during grease heating) and is an important quality indicator of refined cooking oil.

Smoke generation is mainly due to the presence of relatively low-boiling components of fats and oils, e.g. free fatty acid, monoglycerides, and unsaponifiables, with free fatty acid being more volatile than triglycerides. Herein, no significant smoke point differences were observed between oil samples. Moreover, all samples had a BaP contents of < 10 μg/kg and none contained AFB1, in compliance with safety standards. The production of AFB1 in rapeseed is mainly caused by improper storage and can be avoided by maintaining a storage temperature of <27°C, and a rapeseed moisture content of 5–9 wt%. In general, oil C featured basic indicators similar to those of oils A and B and complied with the Chinese standard for flavoured rapeseed oil.

Table 1 presents the fatty acid contents of different oils, showing that oleic acid content (57.76–59.52%) exceeded 55%, thus suggesting that the investigated samples could be classified as oleic acid rich oils. In view of the positive effects of oleic acid, e.g. thrombosis prevention, cardiovascular diseases inhibition, and the reduction of cholesterol levels in blood serum, the elevated content of this acid in fragrant rapeseed oil was concluded to benefit human health. The content of polyunsaturated fatty acids (PUFAs) was 27%, while that of unsaturated fatty acids (USFAs) was >90%. There was no significant difference in fatty acid composition between samples, as all of them were prepared from the same raw material.

3.2 Sensory evaluation and volatile components  
Figure 3 presents the results of sensory evaluation, showing that the rapeseed flavoured and flavoured persistence scores of oil A slightly exceeded those of oils B and C, while the charred and caramel flavoured scores of oil C significantly exceeded those of the other samples. The
comprehensive score of oil C was comparable to that of oil A and exceeded that of oil B. In general, oil C had the highest overall score.

Table 2 lists the chemical compositions and relative activities of oil flavoured substances, showing that according to chemical classes, volatiles could be grouped into aldehydes (15.77%–38.12%), esters (0.94%–2.63%), pyrazines (1.58%–20.83%), and nitriles (25.69%–75.5%). The relative content of nitriles in oil A reached 75.5% and B reached 68.24%, which was significantly different from those in oils C (25.69%), while the relative content of pyrazines in oil C (20.83%) was significantly different from those in oils A (1.58%) and B (4.55%). Finally, the relative content of aldehydes in oil C (38.12%) was 18.87% and 15.77% higher than those in oils A and B, respectively.

The Maillard reaction occurs due to roasting via the interaction of carbonyls with amines during thermal processing\(^2^4\). Pyrazines, which are produced by the cracking of carbohydrates and are important products of the Maillard reaction, usually exhibit nut-like aroma\(^2^5\) and can improve the flavoured of rapeseed oil. All pyrazines can be associated with sensory attributes, including roasted, nutty, coffee-like, woody, and earthy aromas, and significantly contribute to the flavoured of some seed oils\(^2^6\). Consequently, oil C had stronger caramel and charred flavours than oils A and B. As most aldehydes are formed above 90°C, oil C, produced by the high-temperature Maillard reaction, featured a higher relative content of aldehydes. Aldehydes are produced as intermediates of the Maillard reaction and have a strong aroma, good aroma permeability, a very low threshold concentration, and a green grass flavoured\(^2^7\), which can be utilized to produce rapeseed oil, with unique aromas. The content of nitriles, which are responsible for some pungent flavoured of oil\(^2^8\), was higher in oils A and B than that in oil C, and the fragrance of oils A and B was fresher than that of oil C. The combined relative content of aldehydes and nitriles was higher in oil C than those in oils A and B, which explains the slightly higher comprehensive score of oil C.

Oils A and B were produced by a method significantly
Table 2  Volatile chemical composition and ROAV of three kinds of rapeseed oil.

<table>
<thead>
<tr>
<th>Name</th>
<th>Relative content (%)</th>
<th>ROAV</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-butenenitrile</td>
<td>33.52 1.77</td>
<td>/</td>
</tr>
<tr>
<td>propionic acid</td>
<td>2.37 / &lt;0.01</td>
<td>/</td>
</tr>
<tr>
<td>3-methyl-3-butenenitrile</td>
<td>30.03 47.01 21.27</td>
<td>/</td>
</tr>
<tr>
<td>2-methylpyrazine</td>
<td>1.58 1.68 3.08 &lt;0.01</td>
<td>0.01 &lt;0.01</td>
</tr>
<tr>
<td>furfural</td>
<td>12.04 11.25 1.72</td>
<td>0.01 0.13 &lt;0.01</td>
</tr>
<tr>
<td>5-hexonitrile</td>
<td>11.59 17.86 4.02</td>
<td>&lt;0.01 0.06 &lt;0.01</td>
</tr>
<tr>
<td>m-xylene</td>
<td>0.56 / &lt;0.01</td>
<td>/</td>
</tr>
<tr>
<td>benzaldehyde</td>
<td>0.56 / &lt;0.01</td>
<td>/</td>
</tr>
<tr>
<td>5-methyl-2-furaldehyde</td>
<td>4.37 / &lt;0.01</td>
<td>/</td>
</tr>
<tr>
<td>2-thiophene formaldehyde</td>
<td>0.73 / 100.00</td>
<td>/</td>
</tr>
<tr>
<td>2-pyrrole formaldehyde</td>
<td>0.95 / /</td>
<td>/</td>
</tr>
<tr>
<td>nonanal</td>
<td>0.22 0.25 0.44</td>
<td>0.30 8.33 1.14</td>
</tr>
<tr>
<td>ethyl octoate</td>
<td>0.94 2.35 2.10</td>
<td>0.01 0.62 0.04</td>
</tr>
<tr>
<td>benzoisopropionitrile</td>
<td>0.36 1.14 0.40</td>
<td>&lt;0.01 0.08 &lt;0.01</td>
</tr>
<tr>
<td>acetic acid</td>
<td>/ 2.06 /</td>
<td>/</td>
</tr>
<tr>
<td>2,4-pentadienitrile</td>
<td>/ 0.46 /</td>
<td>/</td>
</tr>
<tr>
<td>1,2-bis (methylene) cyclobutane</td>
<td>/ 1.11 /</td>
<td>/</td>
</tr>
<tr>
<td>4-pentenoic acid</td>
<td>/ 0.41 /</td>
<td>/</td>
</tr>
<tr>
<td>2-heptenal</td>
<td>/ 0.64 3.07 /</td>
<td>1.64 0.61</td>
</tr>
<tr>
<td>5-methyl-2-furaldehyde</td>
<td>/ 3.34 /</td>
<td>0.02</td>
</tr>
<tr>
<td>3-butyl isothiocyanate</td>
<td>/ 4.58 /</td>
<td>/</td>
</tr>
<tr>
<td>2-ethyl-6-methylpyrazine</td>
<td>/ 1.01 /</td>
<td>/</td>
</tr>
<tr>
<td>2-ethyl-3-methylpyrazine</td>
<td>/ 0.007 /</td>
<td>0.24</td>
</tr>
<tr>
<td>2-pyrrole formaldehyde</td>
<td>/ 0.29 /</td>
<td>/</td>
</tr>
<tr>
<td>o-cymene</td>
<td>/ 0.16 /</td>
<td>/</td>
</tr>
<tr>
<td>3-ethyl-2,5-dimethylpyrazine</td>
<td>/ 0.03 /</td>
<td>0.90</td>
</tr>
<tr>
<td>undecane</td>
<td>/ 0.14 /</td>
<td>/</td>
</tr>
<tr>
<td>3,5-diethyl-2-methylpyrazine</td>
<td>/ 0.15 /</td>
<td>100.00</td>
</tr>
<tr>
<td>L-bornyl acetate</td>
<td>/ 0.28 /</td>
<td>/</td>
</tr>
<tr>
<td>3-methylbutyraldehyde</td>
<td>/ / 30.95 /</td>
<td>/    100.00</td>
</tr>
<tr>
<td>dimethyl disulfide</td>
<td>/ / 0.32 /</td>
<td>/    0.11</td>
</tr>
<tr>
<td>3-methyl-3-butenenitrile</td>
<td>/ / 21.27 /</td>
<td>/</td>
</tr>
<tr>
<td>octane</td>
<td>/ / 12.12 /</td>
<td>/</td>
</tr>
<tr>
<td>3-methylthiopropanal</td>
<td>/ / 0.19 /</td>
<td>/    2.46</td>
</tr>
<tr>
<td>2,5-dimethylpyrazine</td>
<td>/ / 16.98 /</td>
<td>/    0.02</td>
</tr>
<tr>
<td>methylheptenone</td>
<td>/ / 0.44 /</td>
<td>/    0.02</td>
</tr>
<tr>
<td>2-ethyl-5-methylpyrazine</td>
<td>/ / 0.51 /</td>
<td>/    0.01</td>
</tr>
<tr>
<td>(E,E)-2,4-heptadienal</td>
<td>/ / 0.51 /</td>
<td>/    0.10</td>
</tr>
<tr>
<td>phenylacetaldehyde</td>
<td>/ / 0.79 /</td>
<td>/    0.51</td>
</tr>
<tr>
<td>trans-2-octenal</td>
<td>/ / 0.45 /</td>
<td>/    0.39</td>
</tr>
<tr>
<td>2-ethyl-3,5-dimethylpyrazine</td>
<td>/ / 0.26 /</td>
<td>/    0.67</td>
</tr>
<tr>
<td>cyclohexylsiloxane</td>
<td>/ / 0.38 /</td>
<td>/    /</td>
</tr>
</tbody>
</table>
different from that used to afford oil C, the production of which involved an enzymatic aromatisation of the Maillard reaction furnished pyrazines. Among the numerous compounds produced in Maillard browning model systems, pyrazines are the most abundant flavoured chemicals, contributing to the roasted/toasted flavoured of heated rapeseed oil. Specifically, alkylpyrazines usually formed above 100°C, are important products of the Maillard reaction, or nonenzymatic browning, which involves the condensation of a reducing carbohydrate with an amino compound and is mostly responsible for the flavour and colour of processed rapeseed oil.

In oil A, the only component directly affecting oil odour was 2-thiophene formaldehyde. Moreover, the ROAV of this compound indicated that it had a greater contribution to overall flavoured. In the case of oil B, 3,5-diethyl-2-methyl-pyrazine was concluded to directly affect odour, while nonanal and 2-heptenal had ROAV > 1%, thus imparting important modification effects on the overall flavoured of rapeseed oil B. For oil C, only 3-methylbutyraldehyde had significantly contributing to oil fragrance, and the ROAV of 2-heptenal and 2-ethyl-3,5-dimethylpyrazine indicated that these species had an important modification effect on overall flavoured.

The flavoured ingredients of oil depended on the processing method, with the largest contributors for oils A, B, and C identified as 2-thiophene formaldehyde, 3,5-diethyl-2-methylpyrazine, and 3-methylbutyraldehyde, respectively. According to the sensory evaluation results, oil C had the best fragrance, additionally featuring the highest relative content of 3-methylbutyraldehyde. This substance, produced in the Maillard reaction as an intermediate, has a strong flavoured and is responsible for an overall "roasted" fragrance.

Oils A and B had higher nitrile contents than oil C, which was ascribed to the effects of processing, i.e. to the fact that no squeezing was used for producing oil C. The volatiles exhibited different characteristic flavours, and the rapeseed oil flavoured was synergistically represented by multiple ingredients, not by one or several compounds.

4 Conclusions

The present study compared the effects of production methods (traditional technologies and an enzymatic Maillard reaction) on the basic indicators, fatty acid contents, sensory evaluation scores, volatile components, OAV, and ROAV of flavoured rapeseed oils, showing that the methods had no influence on the basic indicators and fatty acid contents. Fragrant rapeseed oil C had a higher sensory evaluation comprehensive score due to its stronger charred/caramel flavoured than traditionally obtained rapeseed oils A and B. However, these traditionally obtained oils had high contents of 3,5-diethyl-2-methyl-pyrazine and 2-thiophene formaldehyde, which were the largest contributors to fragrance, followed by nonanal and 2-heptenal. In the case of oil C, the largest contributor to fragrance was 3-methylbutyraldehyde, while 2-heptenal and 2-ethyl-3,5-dimethylpyrazine were modifiers of the overall oil flavoured. The flavoured compositions of traditional rapeseed oils (A and B) were significantly different from that of fragrant rapeseed oil (C), which was ascribed to the differences in production methods. The relative contents of individual volatiles were not related to their contributions to fragrance, as many volatile substances show different characteristic flavours. Instead, rapeseed oil flavoured was due to the synergistic effect of multiple ingredients. Furthermore, the contents of BaP and AFB, in fragrant seed oil meet the safety requirements. Thus, it was concluded that through the new process based on the enzymatic Maillard reaction, high-value flavoured rapeseed oil can be produced.

Acknowledgement

The research was supported by National Key R&D Program in the 13th Five year Plan of China (2016YFD0401405-5) and National Natural Science Foundation of China Youth Science Foundation Project (32001735).

References

6) Karbasi, M.; Madadlou, A. Interface-related attributes.

J. Oleo Sci. 69, (12) 1641-1648 (2020)
10) ISO Animal and vegetable fats and oils — Determination of acid value and acidity. ISO 660:2009 EN.
11) ISO Animal and vegetable fats and oils - Determination of peroxide value - Iodometric (visual) endpoint determination. ISO 3960:2017 EN.
12) ISO Animal and vegetable fats and oils - Determination of iodine value. ISO 3961:2018 EN.

1648

J. Oleo Sci. 69, (12) 1641-1648 (2020)