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THE EFFECT OF ROSEMARY EXTRACT ON THE SENSORY QUALITY OF FLAXSEED OIL DURING STORAGE

Abstract: The aim of the study was to evaluate the effect of rosemary extract on the sensory quality of flaxseed oil during storage in practical storage conditions (at room and refrigerator temperature). The flaxseed oil with 0.05% rosemary extract, 0.02% BHT and control sample were subjected to a regular sensory analysis. The intensity of bitter taste, nutty, oxidized and grassy flavours was evaluated with the use of a quantitative descriptive analysis (QDA) by a trained sensory panel. The addition of rosemary extract and BHT in the amount of 0.05% and 0.02%, respectively, to the fresh flaxseed oil did not cause a statistically significant change in its taste perception. Storage in practical conditions revealed beneficial effects of these substances on the sensory quality of the oil as compared to the control samples. The addition of rosemary extract periodically lowered the intensity of a bitter taste. The addition of BHT delayed the appearance of an unacceptable level of bitterness, and thus extended the shelf-life of flaxseed oil by 14 days at room temperature and 28 days under refrigerator storage.

Keywords: cold-pressed flaxseed oil, sensory quality, bitter taste, rosemary extract, quantitative descriptive analysis, storage.

JEL classification: P46, Q16.

WPŁYW DODATKU EKSTRAKTU Z ROZMARYNU NA JAKOŚĆ SENSORYCZNĄ OLEJU LNIANEGO PODCZAS PRZECHOWYWANIA

Streszczenie: Celem badania była ocena wpływu dodatku ekstraktu z rozmarynu na jakość sensoryczną oleju lnianego podczas przechowywania w warunkach praktycz-

nego składowania (w temperaturze pokojowej i chłodniczej). Olej lniany z dodatkiem 0,05-procentowego ekstraktu rozmarynu z dodatkiem 0,02-procentowego BHT oraz próbkę kontrolną poddano badaniom sensorycznym przy udziale przeszkolonego zespołu oceniającego. Oceniano intensywność smaku gorzkiego oraz nuty orzechowej, utlenionej i trawiastej z zastosowaniem metody ilościowej analizy opisowej (QDA). Dodatek ekstraktu z rozmarynu w ilości 0,05% oraz BHT w ilości 0,02% do oleju lnianego nie spowodował sensorycznie wyczuwalnej różnicy w smaku w porównaniu z próbką oleju lnianego bez dodatku na początku eksperymentu. W trakcie przechowywania w warunkach praktycznego składowania stwierdzono korzystny wpływ tych substancji na jakość sensoryczną oleju. Dodatek ekstraktu z rozmarynu okresowo obniżył intensywność smaku gorzkiego, a dodatek BHT opóźnił osiągnięcie nieakceptowanego poziomu gorzkości i tym samym wydłużył trwałość oleju lnianego o 14 dni w przypadku składowania w temperaturze pokojowej oraz o 28 dni w warunkach chłodniczych.

Słowa kluczowe: olej lniany tłoczony na zimno, jakość sensoryczna, smak gorzki, ekstrakt z rozmarynu, metoda ilościowej analizy opisowej, przechowywanie.

Introduction

Polyunsaturated fatty acids are essential nutrients that provide the proper functioning of the human body. To ensure their adequate supply, an increased, but controlled intake should be applied. A valuable source of polyunsaturated fatty acids, in particular α-linolenic acid and other substances with a high biological activity, is flaxseed oil.

Fresh, cold-pressed flaxseed oil obtained from the seeds of good quality is characterized by a golden colour, mild smell and a pleasant, nutty, slightly grassy flavour. During storage, the unfavourable organoleptic changes, especially the formation of a bitter taste, occur, which limit flaxseed oil acceptability. There are some studies focusing on the quantitative and qualitative analysis of compounds responsible for bitterness (cyclolinopeptides) but some research seems to deal with their reduction and improvement of the sensory quality of flaxseed oil during storage. The authors, however, agree that changes in cyclolinopeptides are caused by oxidation processes [Brühl et al. 2007, 2008; Aladedunye, Sosińska, and Przybylski 2013].

There is little research dealing with the efficiency of antioxidant substances in increasing flaxseed oil oxidative stability [van Ruth, Shaker, and Morrissey 2001; Mińkowski 2005; Mińkowski 2008; Omar et al. 2010; Michotte et al. 2011]. The effects of antioxidants were usually expressed as

a prolonged induction period (in the Rancimat test), reduction of primary (e.g. peroxides) or secondary (measured by the p-anisidine value) oxidation products. Among the substances capable of delaying oxidative processes in flaxseed oil were the extracts from oilseeds, rosemary extract/rosmarinic acid, phenolic compounds, tert-butylhydroquinone, and the mixtures of different tocopherols.

Due to the use of different research methods and experimental conditions by various authors, it is highly difficult to compare the effectiveness of antioxidants and identify the most appropriate ones. Moreover, in many works accelerated tests are applied and their results are often not adequate with the studies undertaken at an ambient temperature [Martín-Polvillo, Márquez-Ruiz, and Dobarganes 2004]. A few experiments collate the results of sensory and physicochemical methods to assess the shelf-life of oils, which in the case of flaxseed oil seems to be crucial.

Therefore, the aim of the study was to evaluate the effect of rosemary extract on the sensory quality of flaxseed oil during storage at practical storage conditions.

1. Materials and methods

1.1. Materials

The research material consisted of cold-pressed unrefined flaxseed oil (FO) received directly from the manufacturer. The oil was pressed from the Oliwin variety (high-linoleic acid flaxseed). The use by date determined by the producer amounted to 3 months.

Based on the results of a previous study [Sielicka and Malecka 2013], the addition of 0.05% rosemary extract (FO + 0.05% ER sample) and 0.02% butylhydroxytoluene (FO + 0.02% BHT sample) to flaxseed oil was applied. The commercial rosemary extract (HERBOR 025, Robertet; in liquid form) contained 5–5.5% of active substances: carnosol + carnosic acid, which in the applied dose of 0.05% comprise 25.0–27.5 mg/kg of the sum of carnosol and carnosic acid. According to the regulation of the Minister of Health [Rozporządzenie Ministra Zdrowia z dnia 22 kwietnia 2011 r.], rosemary extract (E392) is permitted for use in vegetable oils below 30 mg/kg calculated as the sum of carnosol and carnosic acid on a fat basis.

All chemicals and solvents were commercially the highest grade and used without further purification.

1.2. Storage conditions

Two practical storage conditions were applied. The samples were kept on the laboratory shelves in closed, dark, glass bottles at room temperature (25°C ± 0.5°C) until the first opening (shop shelf conditions). After analysis the samples were removed from further storage. The oils were placed in a refrigerator (5°C ± 0.5°C) in closed, glass, dark bottles. Every-third day the samples were warmed to the room temperature for 15 minutes, hand shaken and 5 ml of the oil was poured out to simulate real consumers' usage patterns.

The study was carried out twice with a break of a few months and the mean values are presented.

1.3. Methods

Eleven trained panellists familiar with the Quantitative Descriptive Analysis Method [Stone and Sidel 2004] took part in the experiment. The panellists were previously trained according to PN-EN ISO 8586–2:2008. The sensory attributes typical for flaxseed oil were chosen (nutty, grassy, oxidized flavours and with a bitter taste) and the panellists agreed on their definitions. Samples were labelled with a 3-digit code and evaluations of chosen attributes' intensity were made on a 100 mm line-scale anchored with "no perception" and "extremely intensive". The overall quality was assessed with use of the 100 mm line-scale.

Moreover, the question of if the level of bitterness of certain sample determines its rejection from further consumption was enclosed? In the situation where at two succeeding sensory sessions more than 50% of the panellists disqualified the oil due to unacceptable bitterness level, the sample was excluded from the study.

In order to determine whether there is a sensory difference in taste after the addition of antioxidantive substances to flaxseed oil, the same-different method (simple difference test) was applied [ASTM E2139–05 2011]. The test procedure consisted of presenting a single pair of samples to each assessor who evaluated if a detectable difference in taste exists. In each test 100 respondents took part.

The analysis of fatty acids methyl esters was done with use of a Hewlett-Packard HP 5890 gas chromatograph equipped with flame ionization detector and fitted with a Supelcowax-10 column (30m × 0.25mm × 0.25μm) according to the method described by Wąsowicz i Kamiński [1981]. The identification of separated FAME (fatty acids methyl esters) was performed by comparing the retention data of the analysed samples to those obtained for a standard

solution. The results were expressed as a percentage of identified fatty acid in the sum of all fatty acids.

The peroxide value (PV) of all of the samples was measured by the iodometric method according to PN-ISO 3960:1996. The spectrophotometric measurement of the p-anisidine value was done according to PN-ISO 6885:2008. The acid value was assessed by the titration method according to PN-EN ISO 660:2005.

The statistical analysis was performed using the Statistica 10.0 and IBM SPSS 21.0 software packages. The analysis of the results obtained for the QDA method was performed using parametric tests because of the appropriate qualifications and training of the sensory panel and by receiving the normal and close to normal distribution of data [Baryłko-Pikielna and Matuszewska 2009]. For statistical inference for same-different method chi-square test (χ^2) was performed. In the case of the analysis of chemical parameters' results, the parametric tests were applied and basic descriptive statistics (arithmetic mean, standard deviation, coefficient of variation) were calculated. A one-way analysis of variance (ANOVA) was carried out for a comparison of the mean values. The post-hoc Tukey test was used to verify the significance of the differences between the mean values. In addition, a linear regression analysis and correlation analysis were performed. The level of significance was set at $\alpha = 0.05$.

2. Results and discussion

2.1. Characteristics of the research material

Palmitic (16:0), stearic (18:0), oleic (18:1), linoleic (18:2n-6), and α-linolenic (18:3n-3) acids were detected in the cold-pressed flaxseed oil. The total unsaturated fatty acids amounted to 90.1% of the sum of fatty acids. α linolenic acid was the most prevalent fatty acid in the tested oil (54.0%).

At the beginning of the experiment, the flaxseed oil samples exhibited overall high quality and no signs of any oxidation processes were determined. The content of the primary oxidation products measured as peroxide value amounted to 0.84 ± 0.01 meq O_2/kg and the content of the secondary oxidation products expressed as p-anisidine value levelled 0.62 ± 0.01. The amount of free fatty acids achieved 0.64 ± 0.01 mg KOH/g oil. The flaxseed oil met the requirements of the Codex Alimentarius standard for peroxide value and acid value [Codex Standard 19–1981 2013].

The sensory profile of the oil sample was typical for flaxseed oil [Wiesenborn et al. 2005; Brühl et al. 2007]. The intensity of nutty and grassy flavours was at an intermediate level (2.4–2.6 and 3.1–3.2, respectively), while the oxidized flavour was slightly noticeable (0.8–0.9 on 0–10 scale). A bitter taste was detectable but still at a low level (1.9–2.0). The overall quality of the flaxseed oil samples was satisfactory (4.8–4.9) (Table 1 and 2).

The same-different test was used to verify whether there is a sensory perceptible difference in taste at the beginning of the storage period between:
- flaxseed oil with 0.05% ER sample and the control sample,
- flaxseed oil with 0.02% BHT sample and the control sample.

A statistical inference chi-square test (χ^2) was performed. As the level of significance α was 0.05 and the number of degrees of freedom was 1, $\chi^2_{\alpha;(r-1)(k-1)}$ equalled to 3.84. The value of the chi-square test for a couple of samples: FO + 0.05% ER and a control sample was 1.45 and for FO + 0.02% BHT and the control sample reached 0.11. The values of the chi-square test for both pairs were lower than 3.84, which means that at the confidence level of 0.05 consumers did not differentiate samples in terms of taste. The results showed that the addition of antioxidative substances to the oil did not influence the taste of flaxseed oil at the beginning of experiment.

2.2. The impact of rosemary extract and BHT addition on the sensory quality of flaxseed oil during storage

Three oil samples: flaxseed oil with 0.05% rosemary extract (FO + 0.05% ER), flaxseed oil with 0.02% BHT (FO + 0.02% BHT) and flaxseed oil without any additive (FO) were stored at room and refrigerator temperature. The intensity of the sensory attributes and overall quality was evaluated every 14 days by trained panellists. The tests were carried out until the last sample was twofold rejected by more than half of the panellists in succeeding sessions. The experiment lasted 84 days at room temperature and 140 days at fridge conditions.

The one-way analysis of variance (ANOVA) showed significant differences in the sensory attributes and overall quality in all of the samples during storage at either room temperature or fridge conditions.

In the case of nutty flavour, an increase in the intensity during the first 14 days of storage at room temperature was noted in all of the samples. Afterwards, a marked decline until the end of the experiment was recorded (Table 1). The final intensity reached 1.8–2.0 with the initial level ranging from 2.4 to 2.6, which is a slight decrease in this sensory attribute intensity (intensity scale of 0–10). During storage at refrigerator conditions, a more

intense drop in nutty flavour of the flaxseed oil samples was observed and the final intensity was noted at 1.0 level (Table 2). The addition of an antioxidant did not impact the trend of intensity in the changes of the nutty flavour in both storage conditions.

Table 1. The intensity of the sensory attributes of flaxseed oil samples with antioxidants and control sample during storage at room temperature [mean values]

Sensory attribute	Sample	Storage period at 25°C [days]						
		0	14	28	42	56	70	84
Nutty flavour	FO	2.6	3.6	3.4	2.9	2.5	2.0	
	FO + 0.05% ER	2.4	3.6	3.3	2.6	2.2	1.9	
	FO + 0.02% BHT	2.6	3.9	3.5	3.0	2.7	2.2	1.8
Oxidized flavour	FO	0.8	1.2	1.9	2.6	2.9	3.4	
	FO + 0.05% ER	0.8	1.2	1.8	2.5	2.9	3.3	
	FO + 0.02% BHT	0.9	1.3	1.8	2.6	3.0	3.3	3.5
Grassy flavour	FO	3.1	3.1	3.4	3.7	4.1	4.2	
	FO + 0.05% ER	3.2	3.2	3.5	3.9	4.5	4.8	
	FO + 0.02% BHT	3.2	3.2	3.3	3.6	3.6	4.0	4.1
Bitter taste	FO	1.9	2.1	2.8	3.7	4.9	6.8	
	FO + 0.05% ER	1.9	1.9	2.0	2.5	4.0	6.1	
	FO + 0.02% BHT	2.0	1.9	2.4	2.8	3.4	4.8	6.4
Overall quality	FO	4.9	4.3	3.9	3.4	2.5	1.5	
	FO + 0.05% ER	4.8	4.6	4.4	4.0	3.2	1.8	
	FO + 0.02% BHT	4.8	4.5	4.2	3.7	3.4	2.5	1.5

* FO – flaxseed oil, control sample.
FO + 0.05% ER – flaxseed oil with 0.05% rosemary extract.
FO + 0.02%BHT – flaxseed oil with 0.02% BHT.

The regression analysis (with a confidence level at $\alpha = 0.05$) allowed to conclude on the trends of the intensity changes of individual sensory attributes (Table 3). The linear regression model was well matched ($R^2 > 0.500$) in the experiment conducted at fridge temperature in the case of oxidized flavour and bitter taste for all of the samples and for the overall quality of the control sample, which enabled the use of the regression analysis for predicting the changes in the intensities of the selected sensory descriptors of flaxseed oil. A negative trend in the overall quality changes and positive dynamics of the oxidized flavour and bitter taste intensity changes were determined. A good fit of the linear model only for oxidized flavour intensity during storage at room temperature was observed (coefficient of determination R^2 at 0.718–0.741)

Table 2. The intensity of the sensory attributes of flaxseed oil samples with antioxidants and control sample during storage at fridge temperature [mean values]

Sensory attribute	Sample	Storage period at 5°C [days]										
		0	**14**	**28**	**42**	**56**	**70**	**84**	**98**	**112**	**126**	**140**
Nutty flavour	FO	2.6	2.6	2.4	2.3	1.9	1.8	1.6	1.4	1.0		
	FO + 0.05% ER	2.4	2.4	2.2	2.4	1.6	1.5	1.4	1.2	1.0		
	FO + 0.02% BHT	2.6	2.7	2.6	2.7	2.3	2.1	1.9	1.5	1.3	1.2	1.0
Oxidized flavour	FO	0.8	1.4	1.6	1.9	2.2	2.4	2.6	2.7	2.8		
	FO + 0.05% ER	0.8	1.2	1.4	1.8	2.0	2.4	2.6	2.8	2.8		
	FO + 0.02% BHT	0.9	1.3	1.5	1.8	2.0	2.4	2.6	2.7	2.8	2.8	3.0
Grassy flavour	FO	3.1	3.8	3.8	3.7	3.4	3.8	4.1	4.2	4.5		
	FO + 0.05% ER	3.2	3.7	3.9	3.7	3.4	4.1	4.7	4.9	5.0		
	FO + 0.02% BHT	3.2	3.4	3.7	3.7	3.6	3.8	4.2	4.0	4.0	4.0	4.1
Bitter taste	FO	1.9	2.0	2.3	2.8	3.2	3.9	5.5	5.8	6.4		
	FO + 0.05% ER	1.9	1.9	2.1	2.4	2.8	3.5	4.8	5.0	6.0		
	FO + 0.02% BHT	2.0	2.0	2.2	2.4	3.0	3.3	3.9	4.3	4.5	5.4	6.1
Overall quality	FO	4.9	4.5	4.3	4.2	3.9	3.5	2.8	2.5	2.0		
	FO + 0.05% ER	4.8	4.5	4.5	4.4	4.6	3.9	3.4	2.9	2.2		
	FO + 0.02% BHT	4.8	4.5	4.3	4.6	4.5	4.0	3.8	3.3	2.8	2.5	2.1

Abbreviations explained below Table 1.

(Table 3). The increase in the intensity during storage accounted for 0.03–0.04 per day on average (the slope of the regression curve was 0.04, 0.04 and 0.03 respectively for the control sample, FO + 0.05% ER and FO + 0.02% BHT). In the case of storage at 5°C, the intensity of the oxidized flavour increased by 0.01–0.02 per day in all of the samples. The dynamics of adverse changes in the sensory properties were slower during storage in cooling conditions than at room temperature.

The intensity of grassy flavour during storage at room and fridge temperature depended on sample type (Table 1 and 2). At the end of both experiments, the highest marks were received by a sample enriched with 0.05% rosemary extract. The lowest dynamics of intensity changes and the lowest values of grassy flavour were found in the sample with BHT during the entire storage period. The research also showed an increase in the difference between the intensities of grassy flavour in FO + 0.05% ER and FO + 0.02% BHT during storage. Therefore, it could be concluded that the addition of rosemary extract contributed to the increment in the intensity of a grassy note, which was unveiled during storage.

Table 3. The relationship between the intensities of selected sensory attributes and storage period in days (regression significance) for flaxseed oil samples with antioxidants and control sample**

Sensory attribute	Sample	Slope of a line (a)*	y-intercept (b)*	F-statistics	Coefficient of determination R^2	Regression significance
Storage at 5°C						
Oxidized flavour	FO	0.02	1.09	120.34	**0.554**	0.000
	FO + 0.05% ER	0.02	0.93	123.53	**0.560**	0.000
	FO + 0.02% BHT	0.01	1.11	150.73	**0.559**	0.000
Bitter taste	FO	0.04	1.28	464.20	**0.827**	0.000
	FO + 0.05% ER	0.04	1.25	319.11	**0.767**	0.000
	FO + 0.02% BHT	0.03	1.47	522.32	**0.814**	0.000
Overall quality	FO	-0.03	5.04	99.37	**0.506**	0.000
	FO + 0.05% ER	-0.02	5.09	88.60	0.477	0.000
	FO + 0.02% BHT	-0.02	5.08	87.85	0.425	0.000
Storage at 25°C						
Oxidized flavour	FO	0.04	0.79	163.04	**0.718**	**0.000**
	FO + 0.05% ER	0.04	0.80	163.33	**0.718**	**0.000**
	FO + 0.02% BHT	0.03	0.94	214.68	**0.741**	**0.000**

Abbreviations explained below Table 1.
Bold values $R^2 > 0.500$. which shows a good fit for a linear model.
* Intensity of sensory attribute = a * storage period (days) + b.
** In the case of the other sensory attributes of samples the poor fit of the linear regression model was found.

Bitter taste intensity showed the biggest increase among the analysed sensory attributes in the samples stored at 5°C and 25°C (Table 1 and 2). Fresh samples exhibited bitterness at the level of 1.9–2.0 on a linear scale from 0–10. On the 70th day of storage at room temperature, the control sample reached a value of 6.8 and the sample containing 0.05% ER – 6.1. The sample with the addition of 0.02% BHT showed a significantly lower intensity of bitter taste (4.8) and 6.4 after 84 days of incubation (Table 1).

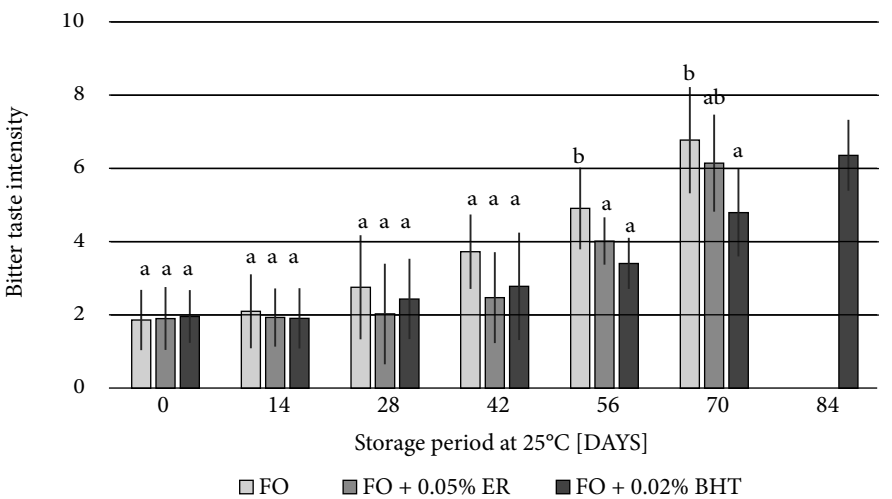
In the case of the experiment conducted at 5°C, after 112 days of storage, the control sample reached a value of 6.4 and the sample containing ER – 6.0 (Table 2). The sample containing BHT showed a significantly lower bitter taste intensity after 112 days, which was 4.5 and only about 140 days of storage in fridge conditions exceeded 6 points.

Considering the whole storage period at 25°C, it was noticed that the flaxseed oil with the addition of rosemary extract showed the lowest intensity of

bitter taste between 14 and 42 day of incubation (Figure 1). This meant that the additive temporarily delayed the occurrence of bitterness. However, in following sessions the panellists detected a bitter taste increase and the level of bitterness was higher than in the sample containing BHT. The increase of bitterness in FO + 0.05% ER sample was parallel with the increase of grassy flavour intensity. A high correlation was found between grassy flavour and bitter taste for FO + 0.05% ER sample ($r = 0.914$).

Similarly, during incubation at 5°C the sample with rosemary extract periodically exhibited the lowest intensity of bitter taste among all of the test samples (56th day of storage) (Figure 2). However, in the following storage days, the intensity increased and was higher than in the flaxseed oil with BHT added. The intense growth of bitterness in FO + 0.05% ER was also parallel with the increasing intensity of a grassy flavour (correlation at $r = 0.923$).

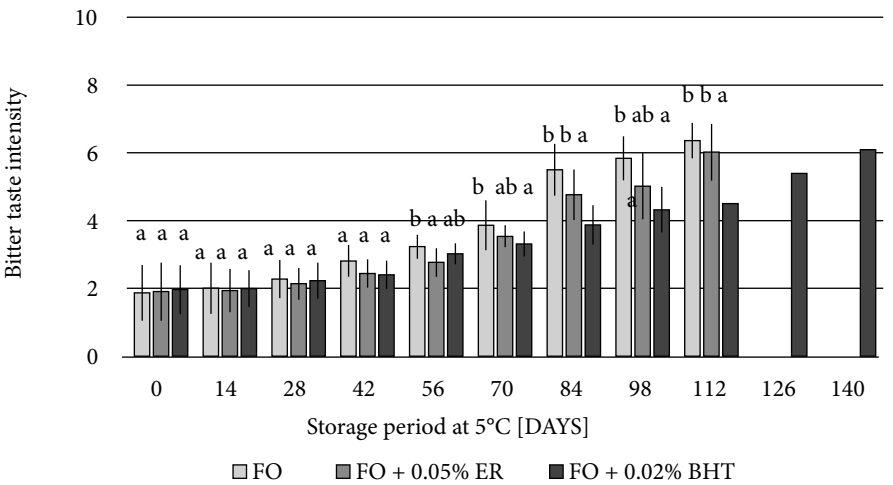
Conducting the post-hoc test enabled to conclude that on the 56th day of storage at room temperature both flaxseed oil samples with rosemary extract and BHT exhibited a significantly lower intensity of a bitter taste than the control sample. On the 70th day of storage only a sample enriched with synthetic antioxidant showed significantly lower bitterness in comparison to the other samples (Figure 1).



Abbreviations explained below Table 1

Figure 1. The intensity of the bitter taste of flaxseed oil samples with antioxidants and control sample during storage at room temperature (mean values marked with different letters within the same day of storage indicate significant differences ($p < 0.05$))

During refrigerator storage, the flaxseed oil with 0.02% BHT showed a significantly lower intensity of a bitter taste than the control sample starting from the 70th day of experiment (Figure 2), which suggests the positive effect of the addition of an antioxidant in the reduction of the intensity of a bitter taste in applied conditions.



Abbreviations explained below Table 1

Figure 2. The intensity of the bitter taste of flaxseed oil samples with antioxidants and control sample during storage at fridge temperature (mean values marked with different letters within the same day of storage indicate significant differences ($p < 0.05$))

According to the obtained results and further statistical analysis, the positive effect of an antioxidant addition (rosemary extract and butylhydroxytoluene) in the reduction of a bitter taste intensity in flaxseed oil during certain periods of storage was stated.

The overall quality of all of the samples significantly decreased during storage. The biggest decline was observed in the control sample incubated at 25°C (Table 1), for which the overall quality after 70 days of storage amounted to 1.5 on a 0–10 scale (initial note – 4.9). Flaxseed oil with rosemary extract reached an equally low overall quality at the end of incubation (1.8). However, this sample showed slightly higher marks in the earlier weeks of storage. During storage in a refrigerator, the drop of overall quality was also observed (Table 2), but the rate of changes was lower, which suggests that

storing the oils in a refrigerator might preserve the desirable organoleptic properties.

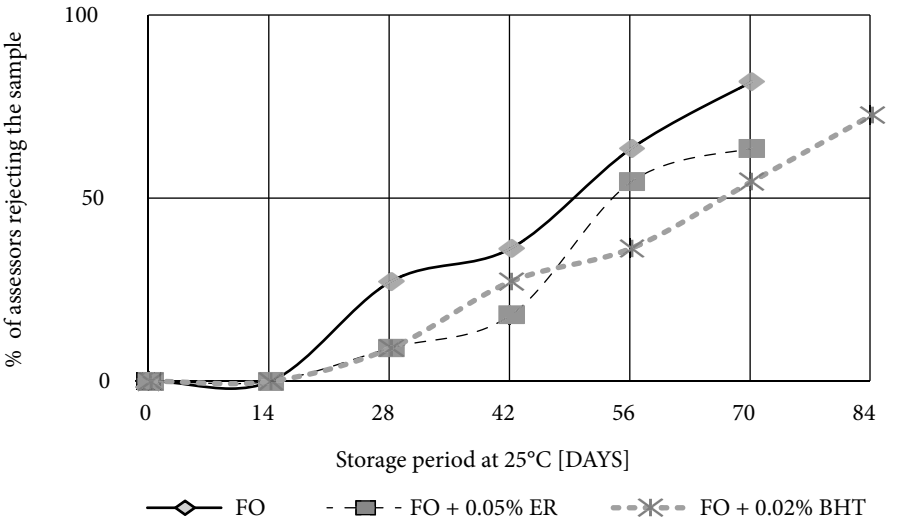
A positive influence of the addition of an antioxidant on the preservation of overall quality of flaxseed oil was determined in both storage conditions.

The decrease in the overall quality was strongly interrelated with the increase of a bitter taste intensity as the high negative correlation between those descriptors was found (r =–0.990 for oils stored at 25°C and r =–0.975 for oils stored at 5°C). A similar strong negative correlation was indicated by Wiesenborn et. al. [2005] for flaxseed oil samples stored at 4°C for 15 weeks (r = –0.990). Moreover, the negative correlation was observed between the overall quality of oils and the intensity of oxidized and grassy flavours. In the fridge conditions, a strong negative correlation was also found between the intensity of nutty flavour and bitter taste of samples (r = –0.926). In contrast, a positive correlation was observed between overall quality and intensity of a nutty flavour (r = 0.703 for oils stored at 25°C and r = 0.900 for oils stored at 5°C).

Due to the strong negative correlation between the overall quality and bitter taste intensity, in this experiment the bitterness was set as a key attribute in assessing the shelf-life of flaxseed oil. On the basis of panellists responses regarding the acceptability of the perceived bitterness of a given sample, the response curve of the percentage of assessors rejecting the sample was drawn (Figure 3 and 4).

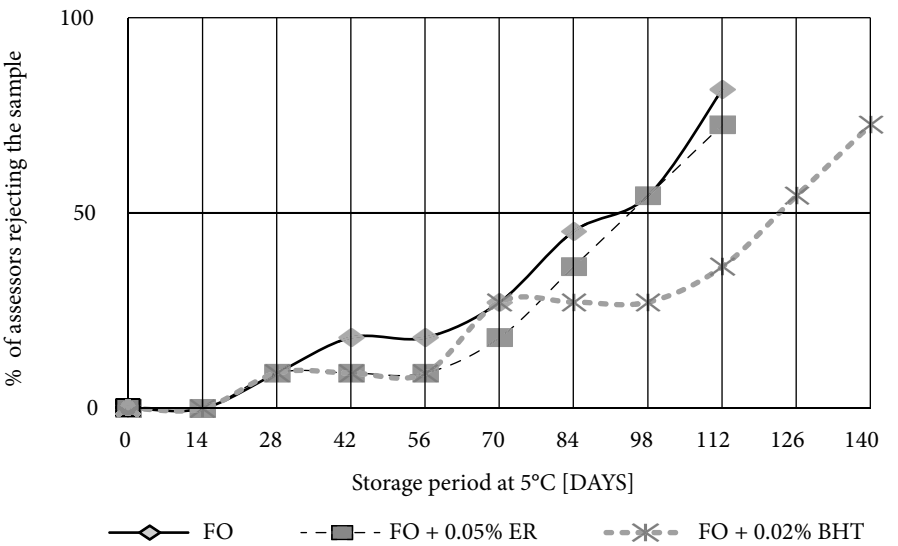
The highest stability during storage at room temperature showed flaxseed oil containing 0.02% BHT (84 days). The control sample and the sample with 0.05% rosemary extract showed a shorter shelf-life amounting to 70 days (Figure 3). The addition of synthetic antioxidant increased the shelf-life of flaxseed oil by 14 days compared to the control sample stored at room temperature, while the rosemary extract additive, in spite of the periodical lowering of the level of bitter taste intensity, did not extend the shelf-life of cold-pressed flaxseed oil stored at 25°C.

In the case of storage in a refrigerator, the shelf-life of the control sample and flaxseed oil with 0.05% ER added, calculated on the basis of an unaccepted level of bitter taste, equalled to 112 days (Figure 4). After 140 days of the experiment, the panellists rejected the sample with the BHT additive. The undertaken research showed that the addition of a synthetic antioxidant extended the shelf-life of oil by 28 days compared to the control sample. As in storage at 25°C, the addition of the rosemary extract did not result in any increased durability of cold-pressed flaxseed oil stored at 5°C, despite a periodical reduction of bitterness level.



Abbreviations explained below Table 1

Figure 3. The percentage of assessors rejecting the samples due to bitterness during storage at room temperature



Abbreviations explained below Table 1

Figure 4. The percentage of assessors rejecting the samples due to bitterness during storage at fridge conditions

The results presented in the literature vary. In the study undertaken by Mińkowski [2005], the addition of α-tocopherol, ascorbyl palmitate and soy lecithin (150 mg/kg) to flaxseed oil extended the shelf-life of the sample stored at room temperature. The conclusions were based on an evaluation of the overall assessment and the limiting level was 3 points on a 5-grade scale.

In a later publication [Mińkowski 2008] the author summarized that during the first two weeks of storage at ambient conditions the most intense changes in the sensory quality of flaxseed oil occurred. Moreover, the intensity of a bitter taste instantly increased while the oxidized and nutty flavours were slightly changed. The author concluded that the addition of antioxidants (a mixture of α-tocopherol, ascorbyl palmitate and soy lecithin at amount of 150 mg/kg) has no noticeable effect on the physicochemical and organoleptic properties of cold-pressed flaxseed oil. Similarly, during storage at fridge conditions (16 weeks) the addition of antioxidants did not influence the intensity and desirability of individual flavours of flaxseed oil samples, which is not in line with results from our study.

Conclusions

The addition of rosemary extract and BHT in the amount of 0.05% and 0.02%, respectively, to fresh flaxseed oil did not cause a statistically significant change in its taste perception. Storage in practical conditions revealed beneficial effects of these substances on selected sensory attributes of the oil.

During storage significant changes in the flavour profile and overall quality of the samples were determined. The addition of rosemary extract periodically lowered the intensity of a bitter taste, but did not extend the shelf-life of flaxseed oil. The addition of BHT delayed the appearance of an unacceptable level of bitterness, and, as a result, prolonged the stability of flaxseed oil by 14 days at room temperature (from 70 days to 84 days) and 28 days under refrigerator storage (from 112 days to 140 days). The addition of antioxidants had a positive impact on the overall quality of oil and helped to retard undesirable sensory changes. In the case of a nutty and oxidized flavour, there was no significant effect of the addition of rosemary extract and BHT on the intensity of these attributes.

Moreover, a significant effect of storage conditions on the sensory quality of flaxseed oils was determined. Although the samples kept in a refrigerator were exposed to oxygen during regular opening, the lower temperature of storage allowed maintaining a higher sensory quality of flaxseed oil estimated on the basis of bitterness acceptability.

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