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Analysis of Hemp Seed Oil Production Methods: Directions for Management of the Niche Oils Production Process in Small-scale Production Facilities

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Abstract

Aim: The market share of edible oils such as flax seed oil, hemp seed oil, pumpkin seed oil, nut oils, and nigella oil is not considerable. Due to the small scale of production and the manufacturers' orientation toward a consumer niche, these oils are classified as niche oils. The purpose of this paper was to compare the cost of producing hemp seed oil (*Cannabis sativa* L.) using four production methods as an example, to compare the physicochemical properties of the oils produced, and to evaluate each of the production methods used.

Methodology: In the study, a cost calculation was made for the start-up of the processing line for each of the selected production methods based on actual inputs. Laboratory tests were conducted on the basic physicochemical parameters of the obtained hemp oils (natural pigment content, fatty acid profile, free fatty acid content, and oxidative stability), and a SWOT analysis of the production methods was performed.

Results: It was found that the production of niche oils by pressing is economically the most reasonable and favourable physicochemical parameter that characterises the oils obtained in this way. The SWOT analysis of the selected production methods indicated the legitimacy of each analysed method and demonstrated its risks.

Implications and recommendations: The analyses presented in this work showed that niche oils should be obtained by pressing (preferably low-temperature) in small oil plants, but this is only appropriate for some raw materials.

Originality/value: There is no legislation in the European Union on the production of niche oils, and it is necessary to set a conceptual framework in which such regulations could be created.

Keywords: niche oils, niche oil production methods, niche oil production costs, break-even point for oil production, SWOT analysis

1. Introduction

The market for edible vegetable oils in Poland is dominated by refined rapeseed oil, produced on an industrial scale (GUS, 2022). The market share of other edible oils, such as flax seed oil, hemp seed oil, pumpkin seed oil, walnut oils, and black seed oil, is marginal. In recent years, the market for edible oils has begun to change, with more and more oils from the seeds and fruits of plants that until recently were not considered a source of edible oils (El-Hamidi and Zaher, 2018). The target buyers of such oils are specific consumers, aware of the impact of a balanced diet on their health and looking for new food products that can enrich this diet (Ganesh and Vakayil, 2019; Ramos-Escurdo et al., 2019). These oils have unique sensory properties and a high content of valuable nutrients, which are removed during the refining process of conventional oils (Hashempour-Baltork et al., 2022; Kaboré et al., 2022). They are called niche oils, reflecting the producers' focus on the particular consumer niche and the small scale of production (Yang et al., 2018).

The physicochemical parameters of niche oils, understood as the characteristics imparted to the product by nature or obtained due to the technological processes used to produce them, vary depending on the employed production method and its modifications (Zhang et al., 2021). Niche oils contain many biologically active compounds (carotenoids, polyphenols, sterols, and tocopherols), minerals, and fat-soluble vitamins. They are distinguished by their favourable fatty acid profile, consisting mainly of the ratio of polyunsaturated (PUFA) and monounsaturated (MUFA) fatty acids (Parthasarathy et al., 2022), which as a high-quality product should be between 2:1 and 5:1 (Esteban et al., 2011; Sagan et al., 2019).

The European Union lacks norms, standards, and guidelines for producing edible niche oils – all the available regulations refer to producing refined oils on an industrial scale (Rapa et al., 2019). In addition, the management of the niche oil production process in small industrial plants must be described in the scientific literature. Niche oil production is often a small-scale regional production (Sidibé et al., 2010); the specifics of managing this process differ from the traditional management model of large-scale enterprises. In small-scale oil production, the most important factors affecting its efficiency and profitability are production costs, consumers' belief in the uniqueness of the product they buy, and ensuring sustainable production, as demonstrated in earlier work (Czwartkowski et al., 2022). Therefore, to systematise knowledge in the area in question, it was necessary to thoroughly evaluate the profitability of investing in individual production methods, their impact on the final product, and their production capabilities, which allows for the development of guidelines for the proper conduct of niche oil production in small production depots.

In the production of niche oils, four production methods are most commonly used: extraction of the raw material with subsequent evaporation of the solvent, e.g. using evaporators, low-temperature pressing (oil temperature does not exceed 40-45°C, high-temperature pressing (oil temperature exceeds 50°C), and pressing combined with partial bleaching of the oil using bleaching earth of known mineral composition (Fathordoobady et al., 2019; Özkal and Yener, 2016; Pohndorf et al., 2016; Pal et al., 2015; Rohman et al., 2021). The choice of production method depends on the type of raw material processed. The produced oil's physicochemical parameters and price may differ, and depend on the appropriate raw material processing technology choice.

For this reason, it is necessary to determine the conceptual framework within which such regulations could be drawn up. The extension of knowledge in the defined research gap should begin with the process characteristics of the various methods of obtaining niche oils. Therefore, the purpose of this study was to compare the cost of producing hemp seed oil (*Cannabis sativa* L.) using four production methods as an example, to compare the physicochemical properties of the oils produced, and to evaluate each of the production methods used. The research was carried out on hemp oil, chosen as a representative of niche oils because of the constantly growing consumer interest in this product and the possibility of obtaining this oil via each defined production method. Based on the analysis of the literature, the following research questions were formulated, the answers to which helped to achieve the set goal of the work:

RQ1: Which method of hemp oil production is economically most feasible?

RQ2: How do the costs of hemp oil production correlate with its physicochemical parameters?

RQ3: Which production method should be used in small production facilities?

2. Methodology

2.1. The Characteristics of the Production Methods

In line with the literature, four methods of hemp oil production were chosen: low-temperature pressing, high-temperature pressing, low-temperature pressing with partial bleaching and extraction. They used a standard industrial hemp seed – Finola – with a seed oil content of 32.47%. The hemp oil in each method was extracted in triplicate by measuring 5 kg of seeds for each trial.

The pressing process was carried out on a single-shaft screw press (with a capacity of 8-24 kg/h depending on the raw material, equipped with a three-phase motor with a power of 1 kW) in two temperature variants. Low-temperature pressing was carried out at a temperature not exceeding 40°C. For high-temperature pressing, the seeds were soaked for 60 minutes at 70°C. The hot seeds were then transferred to a screw press and pressed at >50°C.

For bleaching, 10 dm^3 of oil extracted by low-temperature pressing was used and mixed with 500 g of Sepigel S200RF bleaching earth, based on chemically modified and hydroxylated magnesium silicate, with the known composition given by the manufacturer (Table 1). The amount of bleaching earth was selected based on (Marcinkowski et al., 2022). The mixture thus prepared was introduced into a plate filter to separate the spent bleaching earth.

Table 1. Selected physicochemical properties of bleaching earth used in the process

Density [$g \cdot dm^{-3}$]	pH	Moisture [%, m/m]	Share [%]					
			SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O
350	8	~12	60	3	15	20	0.5	0.05

Source: own elaboration.

For extraction, the hemp seeds were crushed and flooded with 20 dm^3 of n-hexane. The extraction process was carried out for 60 minutes at 20°C with continuous stirring. The solid fraction was then separated from the extract on a Büchner funnel using a qualitative paper sieve under a reduced pressure of 500 mbar. The extractant was evaporated on a rotary vacuum evaporator under a reduced pressure of 100 mbar in the temperature range of 20-65°C, and then the extract was soaked for 15 minutes at 65°C.

2.2. Investment Profitability Analysis

The costs were estimated separately for each production method using a simple apportionment calculation. The unit cost (C_u) was determined by dividing the sum of costs incurred or other inputs in the production process by the number of natural production units (volume of oils obtained). In addition, the quantitative return on investment (BEP) for each production method was estimated as:

$$BEP = \frac{C_O}{(P_u - C_u)}, \tag{1}$$

where: C_o – overhead costs [PLN], P_u – price per unit [PLN], C_u – costs per unit [PLN].

2.3. Laboratory Test Methodology

Regarding physicochemical parameters, the oils produced were compared using four basic parameters: natural pigment content, fatty acid profile, acid number, and oxidative stability.

The determination of chlorophylls and carotenoids was performed spectrophotometrically based on (Wellburn, 1994) and the Polish standard (PN-A-86934:1995). Absorbance measurements were made on a Shimadzu UV-1800 spectrophotometer, calibrated with a blank of 2.5 mL of methanol. Absorbance measurements were performed in triplicate at three wavelengths: 652.4 nm (A), 665.2 nm (B), and 470.0 nm (C). The content of natural dyes in µg/mL of oil was then calculated by substituting the resulting absorbance values into the formulas developed by Wellburn:

$$chlorophyll\ a = 16.72\ \times B - 9.16\ \times A, \tag{2}$$

$$chlorophyll\ b = 34.09\ \times A - 15.28\ \times B, \tag{3}$$

$$carotenoids = \frac{1000 \times C - 1.63 \times (1) - 104.96 \times (2)}{221}. \tag{4}$$

The fatty acid profile was determined based on (Golimowski et al., 2022). Fatty acid methyl esters (FAME) were determined by gas chromatography. A 7890A GC-FID series gas chromatograph (Agilent Tech. Inc., St. Clara, CA, USA) was used. The transesterification of fatty acids was performed according to the official American Oil Chemists' Society (AOCS) Ce 2-66 methods using BF3 (boron trifluoride) solution (Fireston, 1998). Chromatographic separation conditions were consistent with (Wołoszyn et al., 2020). Based on the resulting fatty acid profile, the ratio of n-6 to n-3 polyunsaturated fatty acids (PUFAs) was calculated:

$$\frac{n-6}{n-3}\ PUFA\ ratio = \frac{C18{:}2\ n-6 + C18{:}3\ n-6 + C20{:}3\ n-6}{C18{:}3\ n-3}. \tag{5}$$

The following standard determined the acid number (AV) (PN-EN ISO 660:2021). Approximately 2.5 g of oil was weighed into a ground conical flask and poured into 15 mL of ethanol. The sample was annealed at 60°C for 20 minutes and then titrated with a standard solution of 0.1 M KOH in the presence of phenolphthalein. The acid number value was calculated from the formula:

$$AV = \frac{56.1 \times (V - V_0) \times c}{m}, \tag{6}$$

where: V – volume of KOH solution used to titrate the oil sample, V_0 – volume of KOH solution used to titrate the blank, c – concentration of KOH solution (0.1 M), m – mass of oil dissolved in ethanol.

The oxidative stability testing of the oils was performed after six months of storage at 6°C without UV light. The test methodology was based on (Christodouleas et al., 2015). The absorbance measurements were carried out on a Shimadzu UV-1800 spectrophotometer. The oils' Radical Scavenging Activity (RSA) and the corresponding activities of hydrophilic and lipophilic components were measured using the ABTS method. The percentage change in RSA relative to the blank sample was calculated from the formula:

$$RSA\ (\%) = \frac{A_0 - A}{A_0} \times 100, \tag{7}$$

where: A_0 – absorbance of the blank, A – absorbance of the test sample.

3. Results and Discussion

3.1. Production Cost Analysis

The components of the overhead costs (C_o) were the costs incurred for the materials (bleaching earth, filter media, extraction solvents) and the fixed assets (production apparatus) needed to run the production lines. These costs were estimated according to the actual expenditure incurred to purchase them. The calculations did not include depreciation of individual fixed assets since the expenditure was only for launching and testing the operation of individual production lines, not for operating them over time. The average market price of 1 dm^3 of hemp oil based on Figure 1 (85.96 PLN/dm^3) was used as the unit product price (Pu).

Table 2 shows the expenditure incurred in producing the different hemp oil variants. Hemp seeds were purchased from a local producer for 7.00 PLN/kg and de-oiled according to the methodology described in Section 2.1. All the production methods were repeated three times, recording the power consumption and time required. These values were then averaged and used to calculate individual values for analysing the profitability of each project. The electricity costs were estimated based on the recorded power consumption of a given device during its operation, according to the industrial tariff for the city of Wroclaw, where the study took place. The cost of 1 kWh averaged PLN 2.186 in 2022. The unit cost of producing 1 dm^3 of each oil obtained was calculated, assuming an oil density of 0.900 g/dm^3 for the extracted product mass and a labour price of PLN 19.70 per work hour, the minimum wage rate in 2022 in Poland. Work-hour costs were presented as the product of the minimum labour price and the employee's time input for obtaining oil by the selected method. The quantitative break-even point was then calculated based on relationship (1).

According to the literature, oil extraction with an organic solvent yields about 25-35% more oil than low-temperature pressing (Aladić et al., 2014; Pojić et al., 2014; Shashidhara et al., 2010). However, the execution of the extraction process in small oil plants could be more economically efficient since the BEP of the process is almost four times higher than that of the economically most reasonable option – low-temperature pressing. This effect is due to the too-small scale of production, thus the high ratio of fixed costs to total production, and the neglect of reusing the evaporated solvent. In addition, the extraction process in small extractors significantly increases the changeover time of the station regarding pressing between batches of raw material. Therefore, the recommended production process is low-temperature pressing for small oil plants (with raw material throughput reaching only a few thousand tons per year). The analysis showed that for the production of hemp oil, it is economically unjustified to carry out a high-temperature pressing process or to extend the pressing process to include refining elements. The abovementioned process can only be applied in the case of individual characteristics of the raw material or when the obtained oil has unfavourable organoleptic properties. Some raw materials (e.g. plum seeds) can be difficult to process with low-temperature pressing, therefore conducting an extraction process can be economically justified when pressing is technically impossible. High-temperature pressing may be appropriate to give the product the individual characteristics the consumer desires, e.g. the aftertaste of roasted seeds. Since hemp oil production is a niche production, the ROI analysis should also consider the impact of the process on the physicochemical parameters of the final product, since it is the individual characteristics of the product that affect consumer purchase decisions, as demonstrated in the introduction. A comparison of the physical and chemical parameters of oils is presented in Section 3.2.

Table 2. Summary of the necessary inputs for the production of hemp oils

Production method	Equipment	Equipment cost [PLN]	Electricity consumption [kWh]	Electricity cost [PLN]	Work hour		Average oil yield [dm^3]	C_u [PLN/dm^3]	BEP
Cold pressing	Screw press FARMET®	26 900.00	0.996	2.11	0.48		1.198	43.25	969.25
	Plate filter FARMET®	14 500.00	0.093	0.20	0.25				
	Σ overhead costs	***41 400.00***	***Σ electricity costs***	***2.31***	***Work hour costs** [PLN]*	***14.38***			
Hot pressing	Screw press FARMET®	26 900.00	0.852	1.86	0.43		1.357	56.34	1 515.64
	Plate filter FARMET®	14 500.00	0.682	1.49	0.34				
	Dryer SUP 100	3 499.00	0.115	0.25	1.15				
	Σ overhead costs	***44 899.00***	***Σ electricity costs***	***3.61***	***Work hour costs** [PLN]*	***37.82***			
CP with partly bleaching	Screw press FARMET®	26 900.00	0.996	2.11	0.48		1.138	53.16	1 335.25
	Plate filter FARMET®	14 500.00	0.185	0.40	0.50				
	Mixer CAT R80D	1 450.00	0.008	0.02	0.08				
	Bleaching earth 25 kg	950.00	-	-	-				
	Σ overhead costs	***43 800.00***	***Σ electricity costs***	***2.53***	***Work hour costs** [PLN]*	***20.95***			
Extraction	Burr grinder	2 050.00	0.150	0.33	0.50		1.732	77.06	3 803.82
	Extractor	1 980.00	-	-	-				
	Mixer CAT R80D	1 450.00	0.100	0.22	1.00				
	n-hexane 20 dm^3	6 450.00	-	-	-				
	Büchner funnel	450.00	-	-	-				
	Quality buds	22.99	-	-	-				
	Vacuum pump	4 500.00	0.656	1.43	0.25				
	Evaporator SBS-RV-5000	16 949.00	0.060	0.13	1.50				
	Σ overhead costs	***33 851.99***	***Σ electricity costs***	***1.98***	***Work hour costs** [PLN]*	***64.03***			

Source: own elaboration.

Some costs, such as those for packaging and labelling, promotion and distribution, maintenance of production facilities and warehousing, costs of social insurance for employees and other social benefits, were included in the analysis as they are different for each production plant. Including these components in the analysis was necessary to determine the actual break-even point of investment for individual companies. Moreover, qualified personnel should carry out the extraction process, as it poses many potential risks. Therefore, the estimated human labour costs could be much higher for the extraction process. Costs not covered by the analysis in this paper could increase the break-even point of the investment individually for each company wishing to conduct a similar analysis. However, the analysis clearly showed that starting production lines for niche oils should be based on the low-temperature-pressing process.

3.2. Analysis of Physicochemical Parameters of Extracted Oils

A summary of the tests on the physicochemical parameters of oils obtained by the four methods is presented collectively in Table 3 and then analysed by Principal Components Analysis (PCA) using Statistica 13.3 software (StatSoft, Cracow, Poland).

Table 3. Physicochemical parameters of the tested oils

Parameter	Parameter component	Production method			
		Cold Pressing	*Hot Pressing*	*CP with partly Bleaching*	*Extraction*
Content of natural dyes [µg/mL]	*chlorophyll a*	60.1 ± 4.3	73.6 ± 3.5	10.9 ± 1.2	105.7 ± 4.5
	chlorophyll b	29.0 ± 5.4	42.2 ± 2.1	6.6 ± 0.7	56.6 ± 2.2
	Σ chlorophyll	89.1	115.8	17.5	162.3
	Carotenoids	10.6 ± 2.8	7.4 ± 2.1	1.7 ± 0.5	11.4 ± 1.5
Fatty acid content [%]	*C16:0*	6.52 ± 0.01	6.61 ± 0.02	6.52 ± 0.00	6.61 ± 0.01
	C16:1 n-7	0.07 ± 0.01	0.07 ± 0.01	0.09 ± 0.01	0.08 ± 0.00
	C17:0	0.02 ± 0.00	0.01 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
	C18:0	3.20 ± 0.01	3.19 ± 0.01	3.01 ± 0.00	3.50 ± 0.01
	C18:1 n-9	10.67 ± 0.01	10.56 ± 0.05	11.56 ± 0.02	14.44 ± 0.17
	C18:1 n-7	0.93 ± 0.00	1.03 ± 0.05	0.00 ± 0.00	0.00 ± 0.00
	C18:2 n-6	54.39 ± 0.01	54.21 ± 0.04	55.64 ± 0.03	54.31 ± 0.13
	C18:3 n-6	4.05 ± 0.02	4.25 ± 0.08	5.21 ± 0.01	4.51 ± 0.05
	C18:3 n-3	16.02 ± 0.01	16.03 ± 0.01	16.02 ± 0.01	14.52 ± 0.03
	C20:0	1.26 ± 0.00	1.07 ± 0.09	0.00 ± 0.00	0.00 ± 0.00
	C20:1	0.54 ± 0.00	0.52 ± 0.01	0.41 ± 0.00	0.49 ± 0.06
	C20:2	0.07 ± 0.00	0.07 ± 0.01	0.08 ± 0.00	0.08 ± 0.00
	C20:3 n-6	1.14 ± 0.00	0.45 ± 0.09	0.23 ± 0.00	0.49 ± 0.12
	C21:0	0.31 ± 0.02	1.13 ± 0.01	0.12 ± 0.00	0.87 ± 0.00
	C22:0	0.56 ± 0.03	0.57 ± 0.01	0.11 ± 0.00	0.00 ± 0.00
	C24:0	0.25 ± 0.02	0.23 ± 0.03	0.00 ± 0.00	0.12 ± 0.10
	Σ MUFA	12.21	12.18	12.06	15.01
	Σ PUFA	75.71	75.01	77.18	73.90
	$\frac{n-6}{n-3}\ PUFA\ ratio$	3.67:1	3.68:1	3.81:1	4.08:1
Acid value [mg KOH/g]		0.83 ± 0.02	1.03 ± 0.03	0.70 ± 0.09	2.33 ± 0.02
Radical Scavenging Activity [%]	*hydrophilic components*	2.33 ± 0.35	1.49 ± 0.14	2.18 ± 0.14	1.59 ± 0.00
	lipophilic components	26.71 ± 0.91	28.10 ± 4.42	27.65 ± 1.26	78.10 ± 1.82

Source: own elaboration.

The highest content of chlorophylls and carotenoids was found in extracted oil, which is related to the fact that solvent extraction removes most substances contained in the raw material. The relation between the content of chlorophylls and carotenoids in the samples tested varied depending on the production technology. In each of the samples tested, the chlorophyll content significantly exceeded the carotenoid content by 8 to 15 times, which was also confirmed by (Izzo et al., 2020). In their work (Liang et al., 2015), found that the slightest possible difference between chlorophyll and carotenoid content was most beneficial for oil quality, since green pigments contribute to the autoxidation of oils and carotenoids have an antioxidant effect. Another paper (Liang et al., 2018), showed the effect of the bleaching process on the content of natural pigments, and the results are similar to those obtained in this study.

Extracted oil contains the most conjugated linoleic acid (CLA, C18:1), which improves the digestibility of the oil (Prado et al., 2019), as well as monounsaturated fatty acids. A beneficial n-6/n-3 unsaturated fatty acid ratio, defined by (Petrović et al., 2015) as 3:1, but no more than 4:1, was found in all the samples tested. The study obtained significantly more favourable fatty acid profiles than (Orsavova et al., 2015), which may be because fresh oils were studied immediately after the production process. As (Abdollahi et al., 2020) showed, the fatty acid profile deteriorates during storage as autooxidation of unsaturated fatty acids occurs. The samples' least favourable fatty acid profile tested came from the oil produced by the solvent extraction process. This may be related to subjecting the oil to elevated temperatures during evaporation of the extractant, as indicated by (Alonso-Esteban et al., 2020).

The limit value for the acid value, according to (Teh and Birch, 2013) is 4.0 mg KOH/g oil. In industrial practice, oil whose acid number does not exceed 2.0 mg KOH/g is considered fresh oil. Therefore, pressed oils, especially those partially refined, have a low acid number (Rehman et al., 2013). The results show that increasing the pressing temperature increases the acid number by about 20%, but bleaching the earth can help lower the free fatty acid content (see Ying et al., 2018). The relation between temperature and acid number also explains why AV is highest in extracted oil. This is probably due to the much more prolonged exposure of the oil to elevated temperatures, caused by the evaporation of the extractant.

The oxidative stability of oils is affected by the duration of heat treatment during the extraction process (Özdemir et al., 2021). The significantly higher oxidative stability of extracted oil samples than other samples may be due to the more significant degradation of unsaturated fatty acids, which results from the more prolonged exposure of elevated temperatures to the extracted oil (Rezvankhah et al., 2019). The higher content of unsaturated fatty acids in pressed oils makes them more prone to auto-oxidation, making them less antioxidant-stable and more susceptible to free radicals in the ABTS method. (Symoniuk et al., 2022) showed a correlation between oxidative stability and α-linolenic fatty acid content.

To differentiate the content of physicochemical parameters of the tested oils, a PCA analysis was carried out for the results obtained (Figure 1):

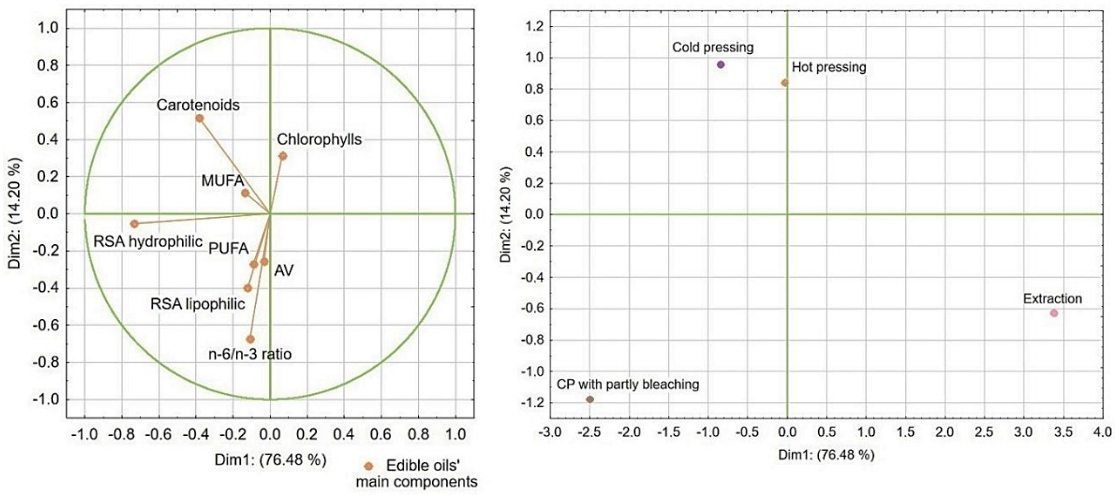

Fig. 1. Principal Component Analysis (PCA) of the load graph and the score plot of data from groups of edible oils' main components

Source: own elaboration.

The analysis of physicochemical parameters showed a wide variation between the niche oil production methods used. Oil subjected to extraction had by far the highest content of the studied parameters, but considering only factors favourable to the quality of the oil, pressing was by far the more effective method. Even the partial refining of edible oils results in a significant removal of nutrients which consumers desire from oil obtained by low-temperature pressing. Based on the above analysis, pressing is the most reasonable method of obtaining niche oils as the ratio of significant nutrients to undesirable components in pressed oils is the most favourable.

3.3. SWOT Analysis of Production Methods

To organize the information from the conducted research and answer the question of which niche oil production technology gives the most favourable results, taking into account economic aspects and the impact on physicochemical parameters of the analysed production methods, it was decided to compile the collected information in the form of four components, using a SWOT analysis (Table 4).

The SWOT analysis of niche oil production methods showed that it was impossible to choose the best production method because it often depends on the type of raw material and the purpose of the oil produced from it. For relatively soft raw materials (e.g. hemp seeds, flax seeds, tomato seeds), one of the methods of pressing the raw material was a much better choice, as indicated by the studies of (Guneser and Yilmaz, 2017) and (Costagli and Betti, 2015). In small-scale production, stamping is a cheaper process that does not require specialist equipment and staff, additionally, it entirely fits in with the sustainable development policy. According to (Deniz et al., 2020; Vaisali et al., 2015), by introducing refining elements and manipulating the temperature of the pressing process, it is possible to adapt the organoleptic qualities of products to the individual needs of consumers. If a partial bleaching or extraction process is used, the need to dispose of hazardous substances must be considered. However, (Boukerroui et al., 2018) indicated that in the case of bleaching earth, it is possible to easily de-oil it, whilst (Loh et al., 2013) claimed that the regeneration and reuse of bleaching earth is not a significant burden for companies, and can significantly reduce the materials necessary for this process. A great advantage of low-temperature pressing is that oils produced in this way quickly obtain quality certificates because this method of oil production is the most ecological, as pointed out by (Manzini et al., 2014). This was confirmed by (Abdul Shukor and Ng, 2022), who defined five key factors influencing the perception of a niche edible oil production method as meeting sustainability standards, namely energy consumption, water life, production materials needed, sewage and waste generated, and gas emissions (including greenhouse gases). According to their study, low-temperature pressing is a method that minimises the factors mentioned above. In turn, Salmani et al. (2022) conducted research based on a SWOT analysis of the generation of post-production waste for various methods of obtaining edible oils. According to that study, oil extraction generates the most considerable post-production waste and often requires long-term storage. Gaurav et al. (2023) drew attention to proper storage of the raw material and its thorough screening before the pressing process, as otherwise it may lead to physical and microbiological contamination of the oil. Mba et al. (2015) claimed that heating the raw material before pressing (conditioning) can prevent microbiological contaminants from entering the oil.

Table 4. SWOT analysis of niche oil production methods

Method	Strengths	Weaknesses	Opportunities	Threats
Cold pressing	• low-cost production method • high nutrient content of the oil • one-step process • short changeover time • sustainable production • retained characteristic aroma of the raw material • no chemical interference with the product	• efficiency lower than obtaining methods • need for oil filtration • not for every raw material • possibility of physical and microbiological contamination of the product	• modification of presses for raw materials that are more difficult to process • ease in obtaining quality certificates • virtually maintenance-free production • growing demand for pressed oil due to the environmental friendliness of the process	• the product may not be fit for direct consumption due to contamination of the raw material • taste too intense for consumers
Hot pressing	• oil yield and process efficiency (higher compared to CP) • high oil nutrient content • no chemical interference with the product	• the need to introduce an additional seed conditioning process • reduced shelf life of the product • possibility of lowering the nutrient content if the temperature is too high • possibility of physical contamination	• possibility of avoiding microbiological risks • less oily pomace will make it easier to extract the remaining substances from the cake • improved waste management • imparting the aroma of roasted seeds	• overheating of the raw material during conditioning • product may not be suitable for direct consumption • taste too intense for consumers
CP with partly bleaching	• minimal amount of undesirable ingredients in the oil • removal of heavy metals • increased product durability • no chemical interference with the product	• significantly reduced nutrient content • the need for double filtration • product loss during bleaching • depriving the oils of the natural flavours of the raw material • additional financial outlays for the purchase and disposal of adsorbents	• possibility of adapting sensory values to the consumer's needs • possibility of regenerating adsorbents • possibility of thermal treatment, increased smoke point • easier conversion into biofuel	• inappropriate selection of adsorbent compositions • used, oily adsorbent is flammable • strict waste disposal standards
Extraction	• oil yield (almost 100% de-oiling of the raw material) • possibility of de-oiling each raw material • process duration	• product contact with chemicals, possible trace amounts of extractant in the product • long-term heating of the product reduces its durability • labour-intensive and energy-intensive process on a small scale • complexity of the process, the need for mechanical intervention in the structure of the raw material • the need for servicing by qualified personnel	• use in plants specialised for one type of oil • possibility of obtaining other, non-fatty substances from the raw material • improving waste management	• risk of explosion or poisoning of people and the environment by solvents • storage of flammable substances and extraction residues • consumer reluctance to purchase a product manufactured using environmentally unfriendly substances • increased inspections of external entities and the need for certification, • rising prices of extractants

Source: own elaboration.

4. Conclusions

Based on the conducted research, it was found that in the case of small production plants, it was economically most justified to conduct the hemp oil production process using low-temperature pressing. Moreover, this pressing also provided the obtained products with the best parameters, constituting features that make niche oils attractive to consumers. Among the tested oils, the least favourable result was for extracted oil, whose physicochemical parameters were worse than for the other oils. This was due to a too long exposure to elevated temperatures, and to the penetration of more substances from the raw material into the oil (including those that negatively affect the product), extraction was also the most expensive production method. The presented case study showed that the most straightforward and cheapest production method (low-temperature pressing) provided hemp oils with the most favourable physicochemical parameters. In further research, it would be worth finding how the evaporation of the solvent at a lower temperature could affect the quality of the oil. The use of the extraction process was not justified economically in small-scale production. In subsequent research, it will be necessary to establish at what scale of production, oil extraction becomes profitable. Extending the pressing process to include the earlier heating of the seeds (high--temperature pressing) or their partial refining was not justified from the economic viewpoint for producing hemp oils. However, this could affect the parameters of other oils, e.g. giving them individual characteristics depending on their future use. It was noted that the obtained oils differ in their organoleptic parameters, such as smell, taste, the intensity of foaming during pouring, and colour. Therefore, the research carried out in this work should be supported by an organoleptic assessment of the obtained oils as the subject of future study. The analyses presented in this paper revealed that niche oils should be obtained by pressing (preferably low-temperature) in small oil plants, but this was only appropriate for some raw materials.

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Analiza metod produkcji oleju z nasion konopi: Kierunki zarządzania procesem produkcji olejów niszowych w małych zakładach produkcyjnych

Streszczenie

Cel: Udział w rynku olejów jadalnych, takich jak olej lniany, olej z nasion konopi, olej z pestek dyni, oleje orzechowe i olej z czarnuszki nie jest znaczący. Ze względu na niewielką skalę produkcji oraz ukierunkowanie producentów na niszę konsumencką, oleje te są klasyfikowane jako oleje niszowe. Celem niniejszego artykułu było porównanie kosztów produkcji oleju z nasion konopi siewnych (*Cannabis sativa* L.) na przykładzie czterech metod produkcji, porównanie właściwości fizyko-chemicznych produkowanych olejów oraz ocena każdej z zastosowanych metod produkcji.

Metodyka: W badaniu przeprowadzono kalkulację kosztów uruchomienia linii przetwórczej dla każdej z wybranych metod produkcji w oparciu o rzeczywiste nakłady. Przeprowadzono badania laboratoryjne podstawowych parametrów fizykochemicznych uzyskanych olejów konopnych (zawartość naturalnych barwników, profil kwasów tłuszczowych, zawartość wolnych kwasów tłuszczowych, stabilność oksydacyjna) oraz przeprowadzono analizę SWOT metod produkcji.

Wyniki: Stwierdzono, że produkcja olejów niszowych metodą tłoczenia jest najbardziej uzasadniona ekonomicznie i charakteryzuje się najkorzystniejszymi parametrami fizykochemicznymi. Analiza SWOT wybranych metod produkcji wykazała zasadność każdej analizowanej metody i wykazała jej zagrożenia.

Implikacje i rekomendacje: Analizy przedstawione w tej pracy wykazały, że oleje niszowe powinny być uzyskiwane przez tłoczenie (najlepiej w niskiej temperaturze) w małych olejarniach, ale jest to odpowiednie tylko dla niektórych surowców.

Oryginalność/wartość: W Unii Europejskiej nie ma przepisów dotyczących produkcji olejów niszowych i konieczne jest ustalenie ram koncepcyjnych, w których takie przepisy mogłyby zostać stworzone.

Słowa kluczowe: oleje niszowe, metody produkcji olejów niszowych, koszty produkcji olejów niszowych, próg rentowności produkcji olejów, analiza SWOT