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Analysis of selected quality parameters of dried herbs available on the European market

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Abstract
International trade in herbs and spices is showing steady growth. This may contribute to the deterioration of their quality (complex supply chains) and the search for alternative, cheaper sources (adulteration). This paper presents the results of quality control of culinary herbs available on the European markets. Eight spices were evaluated: savory, lovage, basil, thyme, marjoram, oregano, fennel, mustard. The tests were performed (from January 2022 till January 2023) for three production batches from five different suppliers, and analyzed such parameters as aroma, overall appearance, impurity content, net weight, moisture content, ash content and essential oils. The analyzed parameters are the basic quality characteristics controlled by institutions overseeing the quality of foodstuffs. The determinations were made on the basis of European standards. The results show deviations from the standards especially in the content of essential oils. Slight exceedances of the standards were also recorded for water and total ash content. On the other hand, for such parameters as net weight, impurity content, general appearance or odor, no overstepping of acceptable standards was recorded.

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1. Introduction

Herbaceous plants (herbs, spice herbs) are a source of aromatic substances (essential oils) used in industrial products (cosmetology, culinary), pharmaceuticals (for humans and animals) and in agriculture (green fertilizers, feed ingredients) (Denys et al., 1990; Neweli-Guz, 2016). They have been cultivated and used for hundreds of years, continually gaining popularity due to their wide spectrum of uses. Moreover, research into determining their antioxidant potential offers opportunities to develop new products with beneficial health effects (Zheng et al., 2001; Nour et al., 2017). However, it is worth noting that fresh herbs are a richer source of biologically active compouds than their dried counterparts (Bieżanowska-Kopeć et al., 2022).

According to FAO data, about 50 thousand plant species are used by humans, while 15-20 thousand species are used for medicinal purposes, accounting for 3-5% of the world's plant resources. About 5 thousand species of plants have been studied for their medicinal properties, and 2 thousand are included in various drug lists (Seidler-Łożykowska, 2009).

Herbal plants are a very important part of the culinary arts, as an additive that improves flavor and aroma and as mentioned previously are used in medicine and in the cosmetic industry. This is due, among other things, to the fact that herbal plants contain biologically active substances, i.e.: essential oils, phenolic compounds, organic acids and vitamins with antioxidant properties, such as vitamin C and carotenoids (Kazimierczak et al., 2011). Essential oils are used as additives in food, beverages, cosmetics, cleaning products and in medicine (Seidler-Łożykowska et al., 2013; Argyropoulos et al., 2014). They are particularly valued for their antibacterial and antioxidant properties and their ability to remove free radicals (Burt, 2004; Sacchetti et al., 2005). In addition, they can be added to food as a natural preservative (Salanță et al., 2022; Ngwatshipane et al., 2023). Some of the herbs also possess anti-microbial and anti-inflammatory qualities (Rubio et al., 2013; Shahidi et al., 2015). Moreover, they have been proven

to have beneficial effects on health without causing any harmful side effects (Nour et al., 2017).

2. Literature review

Nearly 85% of spices are traded internationally with importing countries preparing the final product (processing and packaging). This market is continuously growing which is due, among other things, to the search for low-cost global sources of spices. This phenomenon promotes the implementation of quality systems that guarantee exporters to receive a product that meets certain standards. The largest importers of spice products are the United States, Germany and Japan (Peter, 2012). The EU produces about 100 000 tons of herbs and spices annually and imports about 379 000 tons of spices from non-EU countries (2019 data) (Maquet et al., 2021). The trade in herbs and spices is characterized by a complex supply chain, which provides ample opportunity for adulteration of culinary herbs or reduction of their quality (Székács et al., 2018; Maquet et al., 2021).

Some of the key elements in maintaining the quality of spices and herbs is packaging and storage techniques. Spices and herbs are sensitive to moisture which can lead to clumping, discoloration, rancidity or mold growth. In addition, due to their strong aromatic properties, protection against absorption of foreign odors is extremely important (Peter, 2012; Thamkaew et al., 2021).

Herbs have always been an expensive commodity and prone to adulteration, which can negatively affect their quality (Peter, 2012; Singhal et al., 2003) These products are often among the goods reported as adulterated (Wilkes et al., 2024).The organizations that have implemented quality control regulations for herbs and spices include: American Spice Trade Association, European Spice Association and the International Organization of Spice Trade Association (Osman et al., 2019). According to international guidelines, the quality parameters subjected to the control include: purity, ash content and acid-insoluble ash content, volatile oil content, moisture content, water activity, microbiological testing, pesticide and mycotoxin content, and bulk density and particle size (Peter, 2012).

Analyzing the constantly growing market of spices and herbs and the ease of ruining their quality, the quality control of culinary herbs generally available on the Polish and European market was undertaken. Based on European standards, such parameters as aroma, general appearance, presence of contaminants, net weight, moisture content, ash content and essential oils were determined. The analyzed parameters are the basic quality characteristics controlled by institutions overseeing the quality of foodstuffs.

3. Experimental

The research was conducted in laboratory conditions on herbs and spices bought by purchase. The material for the research came from 5 different suppliers involved in the sale and distribution of herbs and spices on the European market. The material was obtained from online sales offering products to customers from all of the European Union countries. Three batches of test material were purchased from each supplier. All of the herbs and spices were packed in individual packages. The following dried herbs were used in the research: savory, lovage, basil, thyme, marjoram, oregano, fennel, mustard. The herbs were selected due to their widespread use and availability in retail sales on the European market.

The first step of the research was to evaluate the contents of the packages and assess the accuracy and consistency of the information on the labels in accordance with the guidelines of the Regulation of the Minister of Agriculture and Rural Development of July 10, 2007 on the labeling of foodstuffs and the Act of May 7, 2009 on packaged goods. In this regard, the presence of the required information was verified, such as: the name of the foodstuff, the date of minimum durability or expiration date, the manufacturer's identification data, the production batch marking, storage conditions, and the compliance of the given net weight were verified. Each package and its contents were weighed twice on a scale with an accuracy of ±0.01 g. The aroma right after opening of the package, and the overall appearance were evaluated by three lab technician in laboratory condition. In addition, using image analysis, herbs and spices were examined for contaminants. For this purpose, a 40g sample was weighed, and then placed in a specially constructed image acquisition chamber. The acquired images were then analyzed in a proprietary software Patan®, where the objects responsible for the product were marked and information about the proportion of desirable material and foreign material was obtained. In this way, observations were made on the presence of mineral contaminants, mold, the presence of live and dead pests and pest residues. Szwedziak et al., (2011) and Matuszek et al., (2021a; 2021b) presented the usefulness of the computer image analysis in the evaluation of agri-food materials, including mixtures of plant ingredients, along with the methodology. This tool was used by the authors of this study.

Other determinations, i.e. water content, essential oils and total ash, were carried out by drying method (in temperature 105°C) and in accordance with the standards PN-ISO 928:1999 Herbs and spices - determination of total ash by burning the sample at temperature 550±25°C and PN-A-79011-14:1998 Content of essential oils by steam distillation. In the steam distillation method, it is necessary to additionally separate the distillate from water using extraction. The scope of the research carried out presents Figure 1.

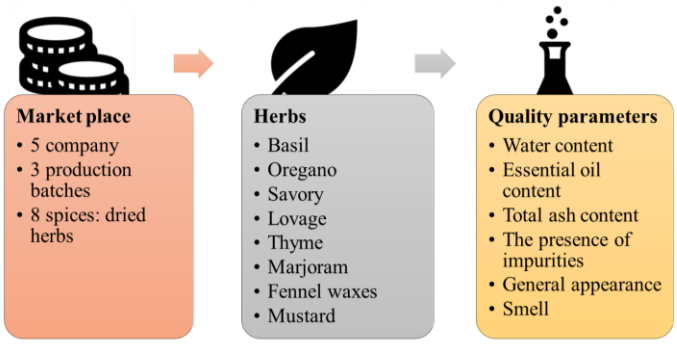

Fig. 1. Research setup

4. Results and discussion

The results obtained were presented in tables (Tables 1-8). However, for the parameters: water content, total ash and essential oils, graphical interpretation was additionally made (Figures 2-4).

Verification of information such as: the name of the foodstuff, the date of minimum durability or expiration date, the manufacturer's identification data, the production batch marking and the storage conditions on the packaging of purchased materials did not reveal any irregularities.

The results obtained for net weight mostly deviated from the manufacturers' declarations on the packaging within the allowed range (Tables 1-8). According to the Act of 7 May 2009 on Packaged Goods (Acta: table 1, appendix 2), for products with weights in the range of 100-200g (purchased packages of dried herbs), the error value can be 4.5%. Only in two cases, i.e. for savory and mustard from the second batch of Supplier 2, it exceeded the permissible level and amounted to 10.92% and 9.04%, respectively. In addition, it was observed that a net weight higher than that stated on the package label was obtained more often.

In the evaluation of general appearance and odor, the presence of non-specific odors or foreign bodies was not noted (Tables 1-8). The presence of contaminants determined by computer image analysis confirmed the lab technician's observations by identifying the material as clean. The above results were obtained for all products analyzed, that is, from three different batches from five suppliers.

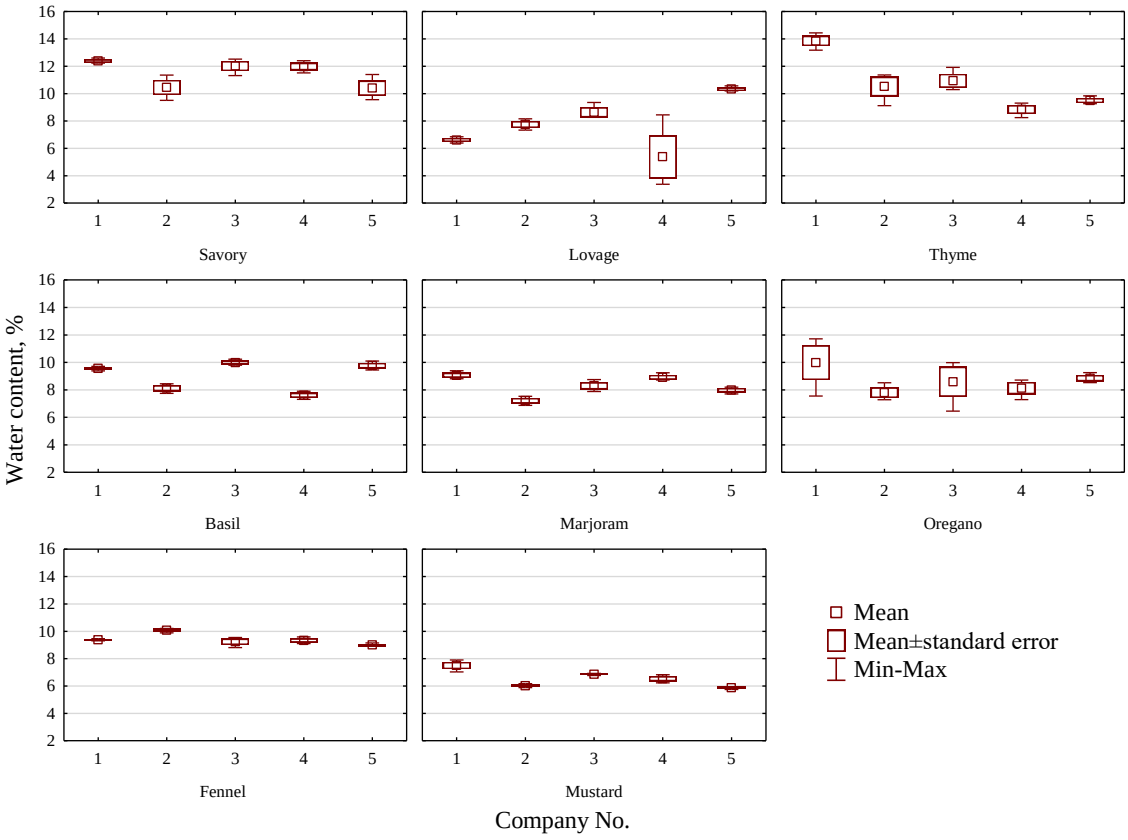

Fig. 2. Results of water content for analyzed spices from 5 suppliers

The analysis of water content showed that standards were exceeded for two products, namely thyme and fennel. In the case of thyme from Supplier 1, an average level of water content (from 3 batches) of 13.75% was obtained, for Supplier 2, 10.7% and for Supplier 3, 11.12% (Table 5, Figure 2). At the same time, the highest level of this parameter was obtained for the product coming from Supplier 1 and amounted to 14.44% for batch 2. It is worth noting that in this case the other two batches also exceeded this indicator (13.18% and 13.93% for batches 1 and 3, respectively). The product from the other two suppliers (4 and 5) was within the standard (up to 10%). For fennel sourced from all five suppliers analyzed, there was an excess of water content. The results exceeded the standard (up to 8%) regardless of the batch tested and their average values were 9.44%, 10.14%, 9.34%, 9.35% and 9.00% for suppliers 1-5, respectively (Table 7, Figure 2). For the remaining products, i.e. oregano, basil, savory, lovage, marjoram and mustard, the water content was within the normal range (Tables 1-4, 6, 8, Figure 2). In addition, the water content for the products from the three batches analyzed did not differ significantly (a small range of standard deviation values). Only in the case of lovage from Supplier 4 and oregano from Suppliers 1 and 3 the standard deviation was higher than in the other cases, at 2.44, 2.01 and 1.83, respectively (Figure 2, Tables 1 and 4). Water content, the degree of water binding, as well as water activity in dried herb raw materials is a factor that

affects its quality and determines the course of chemical and biochemical processes occurring during its storage (Danso-Boateng, 2013). Danso-Boateng (2013) showed that the technique used for drying herbs affects the water content of the final product. The author used five different methods of drying basil (microwave-drying, hot-air-drying, oven-drying, sun-drying and ambient air-drying) and determined a number of parameters for the products so obtained, including performing a moisture content analysis. The lowest moisture content was obtained for raw material dried by hot-air-drying (14.06±1.97), while the highest value of this parameter was obtained for sun-dried (19.71±0.50). In accordance with the results obtained by Danso-Boateng (2013) and Yousif et al., (1999) drying herbs at room temperature also achieves a low water content in the product due to the long process time. Unfortunately, this method, as well as the drying of herbs with hot air and sun drying, adversely affect the nutritional content due to the length of the process, high temperature and/or photochemical decomposition/oxidation processes of organic compounds.

Therefore, the method of drying herbs used has a key role on the final moisture content of the finished product. Water content above the applicable standards can be an indicator of improper drying method or improper storage conditions.

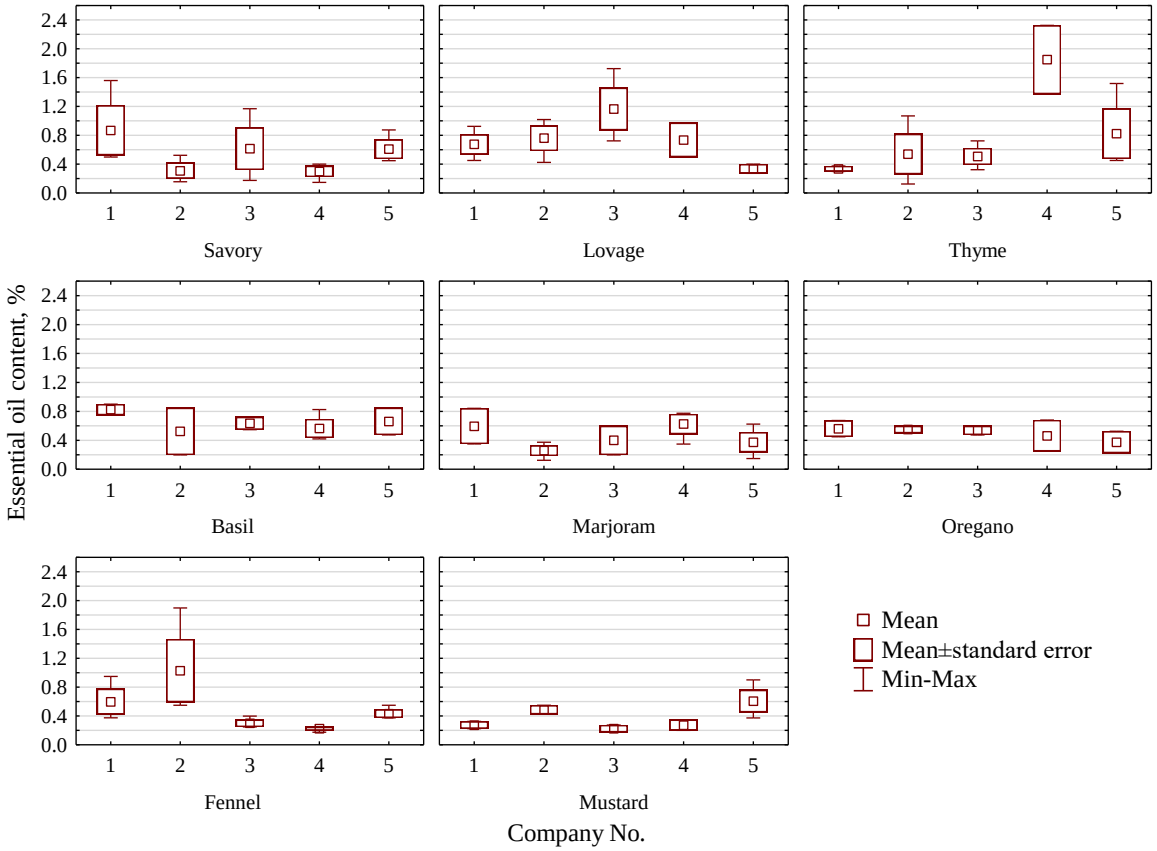

Fig. 3. Results of essential oil content for analyzed spices from 5 suppliers

The analysis of the essential oil content showed correct levels for only two products, i.e. oregano (Table 1) and basil (Table 2). In the case of mustard, there is no question of meeting the requirements due to the lack of such data in the standards (Table 8). In contrast, irregularities were noted for the other five products. In the case of savory, the content of essential oils ranged from 0.30% to 0.87% (average values for 5 Suppliers) with the required minimum content of 1% (Table 3). Only for the product from batch 1 from Supplier 1 was the value obtained in accordance with the standard, i.e.: 1.56%. For lovage, the essential oil content was obtained within the range of the standard (not less than 0.4%) for Suppliers 1-4 (average values: 0.67%, 0.76%, 1.17% and 0.74%, respectively) (Table 4). For the product from Supplier 5, the required level was not obtained (average value 0.34%, Table 4). Thyme from four suppliers (numbered 1, 2, 3 and 5) contained essential oil below the standard (not less than 1.2%) and the obtained average values were in the range of 0.34-0.82%. In contrast, the product from one supplier (No. 4) had this parameter at an average level of 1.85% but with a significant standard deviation of 0.67% (Table 5). Marjoram sourced from four suppliers (numbered 2, 3, 4 and 5) had too low of the essential oil content (standard - not less than 0.7%, Table 6). Only the product from batch 3 from Supplier 1 contained 1.05% essential oil. In the case of fennel, none of the vendors offered a product with the correct essential oil content. The average values obtained for this parameter were in the range of 0.22-1.03% for the required minimum content of 2% (Table 7). In addition, it is worth noting that for this parameter there was

significant variation within the analyzed product batches (highly standard deviation values, Figure 3).

Essential oils are multi-component mixtures of volatile chemical compounds. The content of essential oils and the percentage of individual components varies widely and has highly degree of variability. It depends on many factors, such as the variety of the plant, its stage of vegetation, the geographical area of the crop, the type of fertilization, the processing used or the conditions of their subsequent storage (Alizadeh et al., 2010).

The effect of fertilization on the content and composition of the essential oil of savory was studied by Alizadeh et al., (2010), and showed a significant increase in the content of essential oil in fertilized crops (2.81%) compared to the control crop (1.82%). An analogous relationship was also observed by Omidbaigi et al., (2002) in research using thyme. The authors showed that the application of nitrogen and phosphorus fertilizers significantly affects the essential oil content, while it does not affect its composition (only slight changes in thymol content). The effect of soil type on purple basil growth, essential oil concentration and composition was described by Tursun (2022). The highest essential oil content was obtained for plants grown on sandy soil (0.75%), and the lowest - on clay soil.

Another important factor affecting the content of essential oils is also the drying method used. A study determining the effect of the drying method (air-drying in the shade and in the sun, and oven-drying at 40ºC and 60ºC) was conducted by Hassanpouraghdam et al., (2010). The authors showed that the highest concentration of essential oils was characterized by air-dried basil in the shade (0.9%), slightly lower values were obtained for herbs dried at 40ºC (0.8%), and significantly lower for air-drying in the sun (0.5%) and using a temperature of 60ºC (0.4%). In addition, the authors also compared the composition of the obtained essential oils and showed the presence of significant differences in both qualitative and quantitative composition. The most varied composition was found in the oils obtained from herbs air-dried in the shade.

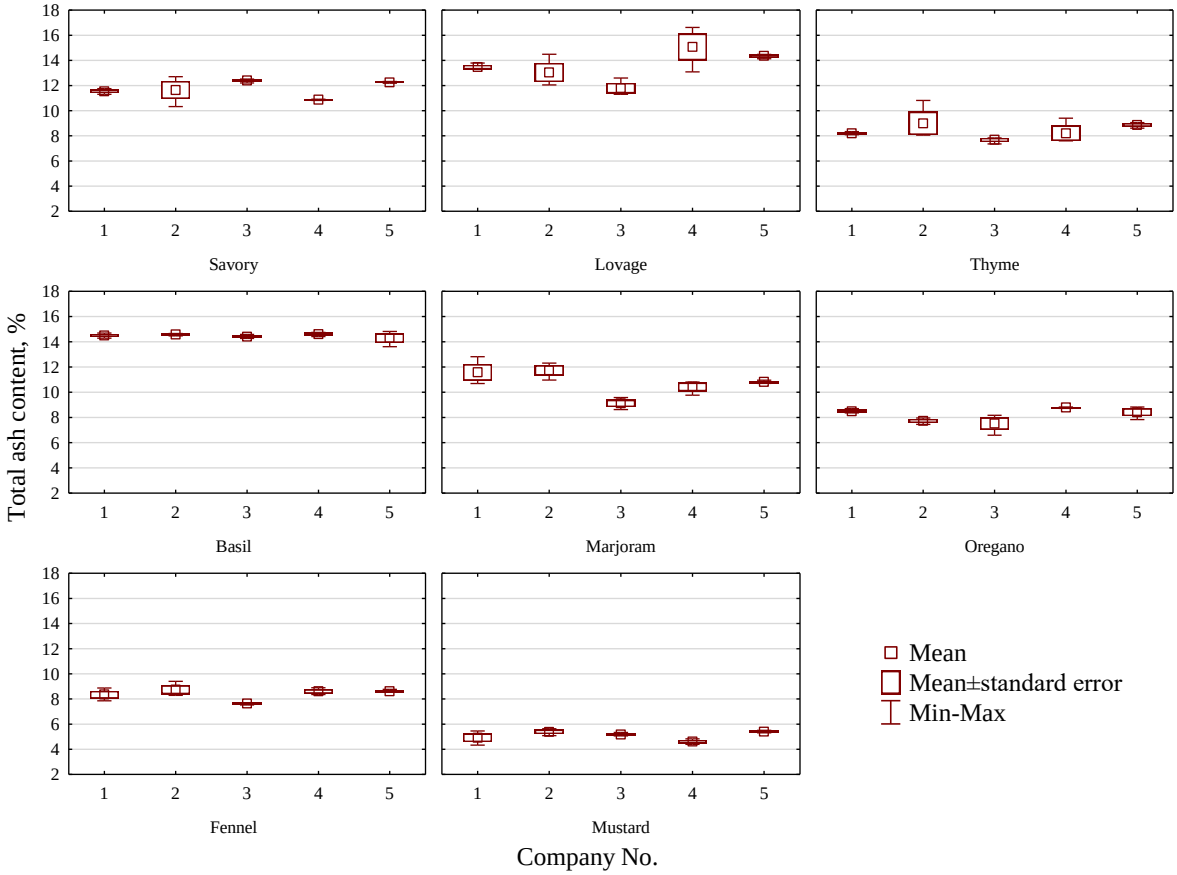

Fig. 4. Results of total ash for analyzed spices from 5 suppliers

With regard to the content of total ash, only lovage did not achieve the required level. For this product obtained from five suppliers, the content of total ash significantly exceeded the standard (up to 8%) and averaged 11.80-15.07% (Table 4, Figure 4). Other products, i.e. oregano, basil, savory, thyme, marjoram, fennel and mustard, were characterized by normal (in accordance with the standard) total ash content (Tables 1-3, 4-8, Figure 4). In addition, for the obtained average values (for 3 batches), small standard deviations were obtained, indicating a slightly variation in quality with regard to total ash content within the analyzed batches (Tables 1-8, Figure 4). Zaguła et al., (2016) obtained similar results for the total ash content in dried basil and oregano samples (average content, respectively 15.09% and 7.81%).

The ash content is one of the key parameters characterizing the quality of dried herbs. Determining the value of this parameter can provide a basis for estimating the mineral content, determining the heavy metal content and the degree of soil/sand contamination (Uba, 2016).

Uba (2016) presented the results of testing the ash content and concentration of heavy metals (Cr, Cd, Mn, Cu, Fe, Pb, Zn and Ni) in selected herb raw materials obtained from the local market. Despite obtaining correct (in accordance with current standards) results of water content in the tested samples, the values obtained for ash and acid-insoluble ash suggested a certain degree of sand contamination. The content of heavy metals examined was high, but within acceptable limits, with the exception of manganese in samples of *Cassia singueana* and *Combretum micranthum*.

The herbs and spices market is assessed as one of the most susceptible to adulteration. Therefore, the European Commission established a coordinated control plan for these products and presented the first results for 2019-2021. The results indicated irregularities for the following samples: 17% for pepper, 14% for cumin, 11% for turmeric, 11% for saffron and 6% for paprika/chili. However, oregano samples turned out to be the most susceptible to contamination with olive leaves (48% of the tested samples). One of the guidelines (in this project) was the total ash content, the values of which were inconsistent with the standards and were considered to indicate adulteration (Maquet et al., 2021). The results of these tests conducted in Poland indicate that 45% of the tested samples did not comply with applicable standards. The non-compliant parameters included, among others: abnormal content of essential oil, total ash or humidity (Office of Competition and Consumer Protection 2019). In the case of the results presented in this study, the largest irregularities were noted for the content of essential oil, which may indicate adulteration.

The obtained results indicate non-compliance with applicable standards. These observations were also made by other researchers, which indicates the importance of the presented topic, and conducting further research in this area seems justified.

5. Conclusion

An analysis of the quality of dried herbs for selected parameters showed irregularities in water, total ash and essential oil content. For the parameters: odor, general appearance and presence of contaminants, there were no exceedances of acceptable standards. The net weight of the purchased products deviated from the seller's declaration, but the values were within an acceptable range. The largest deviations from the standards were observed for the content of essential oils. In this case, only two of the eight products analyzed achieved correct values. For this parameter, the greatest variation was also obtained within the three batches tested.

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Appendix

Table 1. Results of oregano quality assessment

Parameter	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Standard
Net weight, % as compared to the information on the package	96.90 ± 0.75	99.47 ± 0.64	100.53 ± 3.56	101.80 ± 0.44	100.17 ± 0.15	4.5%
Water content, % (m/m)	9.83 ± 2.01	7.88 ± 0.58	8.81 ± 1.83	8.40 ± 0.46	8.91 ± 0.43	Up to 12%
Essential oil content in dry matter, % (m/m)	0.56 ± 0.16	0.55 ± 0.07	0.54 ± 0.09	0.46 ± 0.30	0.37 ± 0.21	Up to 1.5%
Total ash content in dry matter, % (m/m)	8.49 ± 0.17	7.73 ± 0.30	7.71 ± 0.73	8.76 ± 0.13	8.52 ± 0.48	Up to 10%
Presence of contaminants	No presence determined	No presence determined	No presence determined	No presence determined	No presence determined	-
General appearance and smell	Compatible	Compatible	Compatible	Compatible	Compatible	-

Table 2. Results of basil quality assessment

Parameter	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Standard
Net weight, % as compared to the information on the package	100.17 ± 0.85	97.27 ± 2.07	99.97 ± 4.45	101.60 ± 0.79	99.57 ± 0.45	4.5%
Water content, % (m/m)	9.55 ± 0.28	8.20 ± 0.32	10.05 ± 0.28	7.63 ± 0.32	9.58 ± 0.48	Up to 12%
Essential oil content in dry matter, % (m/m)	0.82 ± 0.11	0.56 ± 0.46	0.47 ± 0.31	0.49 ± 0.31	0.66 ± 0.27	Not less than 0.3%
Total ash content in dry matter, % (m/m)	14.50 ± 0.19	14.58 ± 0.18	13.77 ± 1.09	14.56 ± 0.22	14.26 ± 0.80	Up to 17%
Presence of contaminants	No presence determined	No presence determined	No presence determined	No presence determined	No presence determined	-
General appearance and smell	Compatible	Compatible	Compatible	Compatible	Compatible	-

Table 3. Results of savory quality assessment

Parameter	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Standard
Net weight, % as compared to the information on the package	99.90 ± 0.44	94.67 ± 4.83	104.27 ± 2.81	101.00 ± 0.26	101.67 ± 0.12	4.5%
Water content, % (m/m)	12.36 ± 0.25	10.86 ± 1.10	12.12 ± 0.58	11.99 ± 0.32	10.60 ± 1.41	Up to 13%
Essential oil content in dry matter, % (m/m)	0.87 ± 0.60	0.31 ± 0.19	0.62 ± 0.51	0.30 ± 0.13	0.61 ± 0.23	Not less than 1%
Total ash content in dry matter, % (m/m)	11.54 ± 0.39	11.65 ± 1.10	12.41 ± 0.19	10.87 ± 0.13	12.25 ± 0.20	Up to 12%
Presence of contaminants	No presence determined	No presence determined	No presence determined	No presence determined	No presence determined	-
General appearance and smell	Compatible	Compatible	Compatible	Compatible	Compatible	-

Table 4. Results of lovage quality assessment

Parameter	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Standard
Net weight, % as compared to the information on the package	99.27 ± 0.40	99.77 ± 0.40	98.83 ± 2.57	102.00 ± 0.85	100.87 ± 0.75	4.5%
Water content, % (m/m)	6.62 ± 0.43	7.74 ± 0.44	8.64 ± 0.58	5.37 ± 2.44	10.32 ± 0.29	Up to 12%
Essential oil content in dry matter, % (m/m)	0.67 ± 0.24	0.76 ± 0.31	1.17 ± 0.51	0.74 ± 0.34	0.34 ± 0.09	Not less than 0.4%
Total ash content in dry matter, % (m/m)	13.47 ± 0.28	13.04 ± 1.16	11.80 ± 0.64	15.07 ± 1.63	14.35 ± 0.30	Up to 8%
Presence of contaminants	No presence determined	No presence determined	No presence determined	No presence determined	No presence determined	-
General appearance and smell	Compatible	Compatible	Compatible	Compatible	Compatible	-

Table 5. Results of thyme quality assessment

Parameter	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Standard
Net weight, % as compared to the information on the package	99.83 ± 0.32	100.10 ± 1.01	103.33 ± 1.70	99.50 ± 0.66	100.40 ± 0.53	4.5%
Water content, % (m/m)	13.79 ± 0.60	10.73 ± 1.13	11.12 ± 0.80	8.98 ± 0.44	9.47 ± 0.39	Up to 10%
Essential oil content in dry matter, % (m/m)	0.34 ± 0.05	0.54 ± 0.48	0.51 ± 0.20	1.85 ± 0.67	0.82 ± 0.61	Not less than 1.2%
Total ash content in dry matter, % (m/m)	8.19 ± 0.21	8.99 ± 1.45	7.67 ± 0.27	8.21 ± 0.93	8.87 ± 0.21	Up to 15%
Presence of contaminants	No presence determined	No presence determined	No presence determined	No presence determined	No presence determined	-
General appearance and smell	Compatible	Compatible	Compatible	Compatible	Compatible	-

Table 6. Results of marjoram quality assessment

Parameter	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Standard
Net weight, % as compared to the information on the package	100.30 ± 1.35	98.97 ± 0.75	98.87 ± 1.17	101.37 ± 1.10	98.73 ± 1.12	4.5%
Water content, % (m/m)	9.11 ± 0.29	7.12 ± 0.65	8.40 ± 0.44	8.76 ± 0.70	8.02 ± 0.26	Up to 12%
Essential oil content in dry matter, % (m/m)	0.70 ± 0.50	0.26 ± 0.13	0.40 ± 0.28	0.62 ± 0.24	0.37 ± 0.24	Not less than 0.7%
Total ash content in dry matter, % (m/m)	11.57 ± 1.43	11.68 ± 0.85	9.14 ± 0.47	10.36 ± 0.51	10.80 ± 0.27	Up to 16%
Presence of contaminants	No presence determined	No presence determined	No presence determined	No presence determined	No presence determined	-
General appearance and smell	Compatible	Compatible	Compatible	Compatible	Compatible	-

Table 7. Results of fennel quality assessment

Parameter	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Standard
Net weight, % as compared to the information on the package	100.70 ± 1.31	100.47 ± 1.95	100.27 ± 2.35	101.20 ± 0.87	99.10 ± 0.87	4.5%
Water content, % (m/m)	9.44 ± 1.04	10.14 ± 0.39	9.34 ± 0.39	9.35 ± 0.26	9.00 ± 0.60	Up to 8%
Essential oil content in dry matter, % (m/m)	0.60 ± 0.31	1.03 ± 0.75	0.30 ± 0.09	0.22 ± 0.04	0.43 ± 0.10	Not less than 2%
Total ash content in dry matter, % (m/m)	8.34 ± 0.52	8.74 ± 0.65	7.63 ± 0.52	8.60 ± 0.31	8.62 ± 0.38	Up to 10%
Presence of contaminants	No presence determined	No presence determined	No presence determined	No presence determined	No presence determined	-
General appearance and smell	Compatible	Compatible	Compatible	Compatible	Compatible	-

Table 8. Results of mustard quality assessment

Parameter	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Standard
Net weight, % as compared to the information on the package	100.3 ±0.55	96.47 ± 4.73	100.20 ± 0.36	100.90 ± 0.56	100.60 ± 0.46	4.5%
Water content, % (m/m)	7.41 ± 0.70	6.00 ± 0.36	6.87 ± 0.15	6.54 ± 0.41	5.89 ± 0.26	Up to 12%
Essential oil content in dry matter, % (m/m)	0.28 ± 0.07	0.49 ± 0.09	0.22 ± 0.07	0.27 ± 0.11	0.61 ± 0.27	-
Total ash content in dry matter, % (m/m)	4.91 ± 0.52	5.38 ± 0.28	5.18 ± 0.15	4.61 ± 0.22	5.40 ± 0.16	Up to 6.5%
Presence of contaminants	No presence determined	No presence determined	No presence determined	No presence determined	No presence determined	-
General appearance and smell	Compatible	Compatible	Compatible	Compatible	Compatible	-