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PHYSICOCHEMICAL AND MICROBIOLOGICAL PROPERTIES OF THE ZERO-WASTE VEGETABLE SPREADS

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Abstract

Due to avoidance of microbial contamination, external layer and leaves of root vegetables are discarded during food preparation process and these parts may contain many beneficial components. The aim of this study was to use of parts of the vegetables that are normally eliminated by the cleaning process (leaves, peels) for preparation of the vegetable spread and evaluate its microbiological safety, sensorial analysis parameters and physicochemical properties.

An entire vegetable (beetroot, parsnip, carrot) with leaves and peels was used to prepare zero-waste vegetable spreads while cleaned vegetables was used the preparation of the traditional kind. The results of the sensory analysis (using a 5-point hedonic scale) and the chemical (energy content was measured using a bomb calorimeter; water activity was performed using a water activity analyser; in addition, moisture content, carbohydrate content, fat content, protein content and ash content were evaluated using AOAC established procedures) and microbiological assays (the determination of the total number of microorganisms, coliform bacteria, *Salmonella* spp., and *Klebsiella* spp. was performed using ISO methodologies) of the zero-waste vegetable spread and the traditional kind were compared to evaluate the impact of the usually eliminated parts of the vegetables on the organoleptic properties, shelf life and nutritional value of the product. The accuracy was measured by calculating the average value of 3 - 5 measurements. The data was analysed by using Microsoft Excel 2021 and the data analysis software RStudio. The Student's t-test was applied to indicate a significant difference at a 95% confidence level.

The results showed that the content of minerals, moisture and calories were higher in the zero-waste products ($p < 0.05$), instead there was no significant difference in water activity, protein, fat content and carbohydrate content ($p \geq 0.05$). The microbiological assays showed that the carrot spreads with the zero-waste and traditional preparation methods had a shelf life of 3 and 4 days, respectively; shelf life of the beetroot spreads was 3 days and that of the parsnip spreads was 5 days. The zero-waste cooking method can change the sensory aspect of a product. The carrot spread without waste had a green appearance instead of the orange colour. The zero-waste beetroot spread was more red and sweeter than traditionally prepared beetroot spread. The sour taste of the parsnip spread was less intense by the zero-waste cooking method than the traditional kind.

In conclusion, the use of external layer and leaves of root vegetables increased the content of minerals, moisture and calories of vegetable spreads and it is microbiologically safe. Furthermore, it appeals to consumers' senses.

***Key words**: Zero-waste, Beetroot, Carrot, Parsnip, Vegetable spread.*

1. Introduction

Food waste is a growing problem due to packaging, rejection of substandard products, overcrowding on shelves and the various steps involved in food processing. According to the Food and Agriculture Organisation, about 1.3 billion tonnes of food is wasted every year. During the process of root vegetable-based

food preparation external layers of root vegetables are discarded to decrease the risk of microbial contamination. Also, to remove parts of the vegetable which does not have the appearance to meet consumers' expectation.

External layers of food vegetables are also commonly disposed of due to their tough composition [1]. Root vegetables are excellent sources of: carbohydrates, vitamins, microelements, fibres, antioxidants, water, carotenoids, and are also low in fats and cholesterol, and calories [1, 2].

Vegetable spreads are a kind of meal in which preparation could use whole vegetables despite their appearance because, during the process of preparation, vegetables are blended. Various dips and vegetable spreads are not widely analysed products and often in their preparation process do not include pasteurization, the use of preservatives or other methods which reduce microbial contamination [3].

In previous years there has been increasing demand for vegetarian, organic and ecological food. People, identifying themselves as vegans, vegetarians or flexitarians increase their consumption of vegetable, fruit and grain-based meals [3]. Due to this also variety of vegetable spreads, dips, relishes and chutneys and their supply in the market is growing.

Carrot (*Daucus carota* subsp. *sativus*), beetroot (*Beta vulgaris*), and parsnip (*Pastinaca sativa* L.) are root vegetables which are traditionally cultivated in Lithuania and due to their long shelf life are stored and widely used during the cold season for preparation of soups, stews, chutneys, salads and spreads. All these root vegetables are rich in minerals, fibres, vitamins, antioxidants and phytonutrients [4, 5, 6, and 7]. The main components of parsnip are starch, around 50% w/w and dietary fibre, such as cellulose and hemicelluloses [8, 9, and 10]. Beetroots are considered low-starch root vegetables, composed of pectin polysaccharides and cellulose, which contain a high content of ferulic acid [10, 11]. The carrots are rich in carotenoids, anthocyanins, and dietary fibres (such as hemicelluloses, cellulose and pectic polysaccharides) [12, 13].

The aim of this study was to use of parts of the vegetables that are normally eliminated by the cleaning process (leaves, peels) for preparation of the vegetable spread and evaluate its microbiological safety, sensorial analysis parameters and physicochemical properties.

2. Materials and Methods

2.1 Materials and sample preparation

Fresh ingredients such as: carrots, parsnips, beetroots, cashew nuts, lime, ginger, pine nuts, and fresh basil were purchased in local supermarkets (UAB Sanitex, Kaunas, Lithuania). Also, for preparation of spreads were used tahini (Sesali Tahini Sesame, China), olive oil (Manfredi Barbera and Figli, Italy), salt (Deltasal, Spain), pepper (Wiko, GUNZ Warenhandels, Austria), Parmesan cheese (Granarolo, Italy), Sesame oil (Jade Bridge, Zhongshan Desly Foodstuffs, China).

Microbiological analysis was performed by using Plate Count Agar (PCA, EMD Chemicals, Canada), Chromogenic *Salmonella* Selective LAB-agar (CSA, Biomaxima, Poland), Violet Red Bile with Glucose LAB-agar (VRB, Biomaxima, Poland), sodium chloride (Cellpure® ≥99,5 %, Roth, Germany), an incubator (Bact incubator, Trade Raypa, Spain), masticator homogenizer (IUL S.A., Spain), Petri plates (Roth, Germany), blender bags (VWR International, USA), colony counter CC-1 (Boceo, Germany), sterile 1 mL pipettes (Biosigma, Italy), and pipette filler (Glasfirn, Germany).

2.1.1 Carrot spread recipe

Ingredients: 100 g carrots, 40 g cashew nuts, 40 g water, 20 g lime juice, 40 g tahini, 60 g olive oil, 5 g ginger, salt, and pepper. Preparation: cashews were placed in a bowl and covered with water to soak, meanwhile the carrots were washed well, peeled and sliced (carrots are just very well washed and sliced in a zero-waste recipe). The carrots were mixed with the ginger and poured into a plastic bag for vacuum. The mixture is cooked in *sous vide* for 70 min (80 ^{0}C). After *sous vide* cooking vegetables are mixed with soaked cashews and the rest of the ingredients and blended in a food processor until a smooth consistency is reached (approximately 5 min).

2.1.2 Parsnip spread recipe

Ingredients: 100 g parsnips, 25 g cashew nuts, 10 g crushed garlic, 20 g lime juice, 40 g olive oil, salt and pepper, tip of teaspoon paprika powder, 20 g tahini, and 10 g water. Preparation: parsnips were washed well, peeled and sliced (parsnips are just very well washed and sliced in a zero-waste recipe). The sliced parsnip and cleaned garlic were poured into a plastic bag for vacuum and cooked *sous vide* for 60 min (80 ^{0}C). Meanwhile, the cashew nuts were baked with a little bit of olive oil until they were browned. After *sous vide* cooking vegetables are combined with roasted cashews and the rest of the ingredients and blended in a food processor until a smooth consistency is reached (approximately 5 min).

2.1.3 Beetroot spread recipe

Ingredients: 100 g beetroot, 5 g crushed garlic, 25 g

pine nuts, 40 g grated Parmesan, 20 g sesame oil, 40 g olive oil, salt, and pepper. Preparation: beetroots were washed, peeled and sliced into thin slices (beetroots are just very well washed and sliced in a zero-waste recipe). The sliced beetroot and garlic were poured into a plastic bag for vacuum and cooked *sous vide* for 90 min (80 ^{0}C). After *sous vide* cooking the beetroot and garlic are poured into a food processor with the rest of the ingredients and blended in a food processor until a smooth consistency is reached (approximately 5 min).

The list of vegetable spreads and its abbreviations is given in Table 1 and these abbreviations are used in all tables and graphs of the analysis results.

Table 1. List of spreads and their abbreviations

Spread	Spread abbreviation
Carrot spread zero-waste	Carrot ZW
Carrot spread original recipe	Carrot TR
Parsnip spread zero-waste	Parsnip ZW
Parsnip spread original recipe	Parsnip TR
Beetroot spread zero-waste	Beetroot ZW
Beetroot spread original recipe	Beetroot TR

2.2 Nutritional composition analysis

The vegetable spreads were analysed for nutritional composition, including moisture: content, carbohydrate content, fat content, protein content and ash content using AOAC [14] established procedures. The protein content was calculated by multiplying the nitrogen amount by a factor of 6.25 [15].

2.3 Calorie content evaluation

Determination of the calorific value of the vegetable spreads was performed by using a calorimetric bomb. Calorie content evaluation was performed by using a calorimeter (C200, IKA, Germany).

2.4 Microbiological analysis

The vegetable spreads were analysed for the determination of the total number of microorganisms, by using standard methodology - LST EN ISO 4833-1:2013/AMD 1: 2022 Microbiology of the food chain - Horizontal method for the enumeration of microorganisms - Part 1: Colony count at 30 ^{0}C by the pour plate technique [16].

The determination of coliform bacteria in the vegetable spreads was made by using standard - LST EN ISO 4832:2006 Microbiology of food and animal feeding stuff - Horizontal method for the enumeration of coliforms - Colony-count technique [17].

Also, the vegetable spreads were analysed to evaluate the content of *Salmonella* spp. and *Klebsiella* spp. Bacteria by using standard methodology - EN ISO 6579-1:2017 Microbiology of the food chain - Horizontal method for the detection, enumeration and serotyping of *Salmonella* - Part 1: Detection of *Salmonella* spp. and *Klebsiella* spp. [18].

2.5 Determination of water activity

The water activity (a_w) measurements of vegetable spreads were performed using a water activity analyser (Hygropalm - HP23-AW-A, Rotronic, Bassersdorf, Switzerland) by loading 2 ± 0.5 g of the sample into the sample holder at 22 ± 2 ^{0}C. Before analysis, the water activity analyser was calibrated using the probes with the certified Rotronic humidity standards.

2.6 Sensory evaluation

A sensory analysis based on the questionnaire to evaluate the: appearance, colour, flavour, texture, taste and overall acceptability of vegetable spreads was distributed among respondents. A group of 30 respondents were used to evaluate the sensorial properties by using a 5-point hedonic scale, where: 1 - poor, 2 - average, 3 - fair, 4 - good, and 5 - very good.

2.7 Statistical analysis

Statistical analysis of the results was performed by using Microsoft Excel 2021 and the data analysis software RStudio [19]. The accuracy was measured by calculating the average value of 3 - 5 measurements. The precision of measurements was determined by calculating the relative standard deviations. The Student's t-test was applied to indicate a significant difference at a 95 % confidence level. The results in the graphs and the tables are presented as an average of the measurements ± RSD (relative standard deviation).

3. Results and Discussion

3.1 Nutritional composition

The results of the nutritional composition of the vegetable spreads demonstrate that the content of moisture, fat, protein, minerals and carbohydrates differ in zero-waste and traditionally prepared vegetable spreads. The results of the analyses were calculated as an average of three replicates and also standard deviation was calculated. The analysis results of fat, protein and carbohydrate show that there is no statistically significant difference between samples ($p \geq 0.05$).

As presented in Table 2 moisture content in the vegetable spreads varied in the range 37.67 - 46.19 % and was slightly higher in the zero-waste vegetable spreads. The highest water content was in the beetroot zero-waste and traditionally prepared spreads,

respectively 46.19 % and 44.63 %. The highest content of water was in the beetroots among analysed root vegetables.

Analysis results of fat, protein and carbohydrate content demonstrate that the difference in the zero-waste and traditionally prepared vegetable spreads was not statistically meaningful ($p \geq 0.05$).

All the spreads were low in fat amount. The lowest fat content was in the zero-waste and traditionally prepared beetroot spreads, respectively 0.62 % and 0.65 %, and the highest in the zero-waste and traditionally prepared spreads of parsnip, respectively 0.82 % and 0.86 %. Due to the low content of fats vegetable spreads can be a healthy replacement for butter or margarine-based spreads. According to the results of the research of Colgan and colleagues [20] regular usage of phytosterol-enriched food could decrease cholesterol levels, so beetroot spreads could be a healthier dietary choice for the reduction of cholesterol levels.

Carbohydrate content in the vegetable spreads was 40.69 % - 54.64 %. Among analysed vegetable spreads beetroot spreads had the lowest and carrot spreads had the highest content of the carbohydrates.

All analysed vegetable spreads are based on root vegetables, rich in dietary fibre which has a positive impact on human health because can reduce the risk of cardiovascular diseases [10].

The protein content of zero-waste and traditionally prepared carrot spreads was slightly higher in the zero-waste samples than in traditionally prepared, 6.20 % and 5.36 % respectively. Similar tendencies were in the parsnip spreads, also zero-waste spread had a higher content of proteins than traditionally prepared, 6.25 % and 6.15 % respectively. Only traditionally prepared beetroot spreads had a higher content of proteins than zero-waste samples, 10.44 % and 9.93 % respectively. The high concentration of proteins in the analysed vegetable spreads was related to other ingredients used for spread preparation, such as cashews or pine nuts.

Mineral content was significantly ($p < 0.05$) higher in zero-waste vegetable spreads. The highest content of minerals was found in the zero-waste and traditionally prepared beetroot spreads, 2.56 % and 2.17 % respectively. Beetroot peels are a good source of micronutrient minerals, and potassium and also have high total phenolic content and antioxidant capacity [21]. The lowest content of minerals was found in the zero-waste and traditionally prepared carrot spreads, 1.94 % and 1.51 % respectively. Researcher Mohady *et al.*, [22], demonstrated, that the peel of vegetables is a good source of dietary fibre and has strong antioxidant activities.

3.2 Calorie content

Results of calorie content determination shown in Table 3 show that zero-waste carrot spread had significantly ($p < 0.05$) higher calorie content than traditionally prepared, respectively 286 kcal/100 g and 260 kcal/100 g. It can be concluded that the usage of all the parts gives a higher calorie content. For parsnip and beetroot spreads, the calorie content is significantly lower when cooking without waste. Among analysed vegetable spreads calorie content was significantly higher in the beetroot ones due to other ingredients used for preparation of the spread, such as pine nuts and Parmesan cheese.

Table 3. Calorie content of the vegetable spreads. Results represent the average and standard deviation (n = 3). The Student's t-test indicates a significant difference between samples ($p < 0.05$)

Parameters	Calorie, kcal/100g
Carrot ZW	286 ± 1.11
Carrot TR	260 ± 0.98
Parsnip ZW	237 ± 1.89
Parsnip TR	254 ± 1.00
Beetroot ZW	340 ± 0.93
Beetroot TR	342 ± 1.31

3.3 Microbiological analysis

Microbiological analysis results show (Figure 1), that the count of aerobic microorganisms in the traditionally prepared carrot spreads is lower than the average amount in the zero-waste sample and the shelf life was four and three days respectively. This is expected because cooking with the peeling and green leaves of the carrots makes it more difficult to clean the product perfectly.

Table 2. The nutritional composition of the vegetable spreads

Parameters	Moisture, %	Fat, %	Protein, %	Minerals, %	Carbohydrate, %
Carrot ZW	38.58 ± 1.16	0.80 ± 1.98	6.20 ± 5.10	1.94 ± 1.75	52.48 ± 3.06
Carrot TR	37.67 ± 0.61	0.83 ± 1.90	5.36 ± 1.13	1.51 ± 1.43	54.64 ± 3.47
Parsnip ZW	39.77 ± 0.23	0.82 ± 1.78	6.25 ± 0.51	2.32 ± 1.36	50.77 ± 0.61
Parsnip TR	39.27 ± 0.29	0.86 ± 1.93	6.15 ± 0.62	2.08 ± 1.23	52.22 ± 1.95
Beetroot ZW	46.19 ± 0.27	0.62 ± 3.61	9.93 ± 0.29	2.56 ± 3.22	40.69 ± 3.76
Beetroot TR	44.63 ± 0.17	0.65 ± 4.87	10.44 ± 2.78	2.17 ± 3.24	42.20 ± 3.81

The parsnip spread had the lowest content of microorganisms and the longest shelf life, five days, among different vegetable spreads. Instead, the shortest shelf life was of the beetroot spreads, only two days. The third-day aerobic bacteria count was 2.14 x 10^4 CFU/mL and 2.53 x 10^4 CFU/mL in the zero-waste and traditionally prepared vegetable spreads respectively.

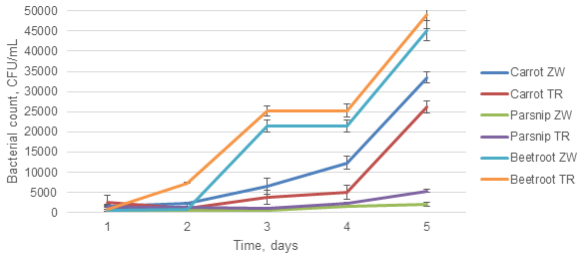

Figure 1. The presence of aerobic bacteria counts in vegetable spreads. The values represent the average and standard deviation of five replicates

The presence of faecal coliforms and *Salmonella* spp. bacteria were not detected in the analysed vegetable spreads (Table 4). Instead, it was found *Klebsiella* spp. bacteria in the vegetable samples. The highest count of *Klebsiella* spp. bacteria was found in the zero-waste and traditionally prepared beetroot spreads, 4.68 x 10^2 CFU/mL and 6.32 x 10^2 CFU/mL respectively. *Klebsiella* spp. bacteria was not detected only in zero-waste carrot spread, instead, 7.6 x 10^1 CFU/mL was found in the traditionally prepared carrot spread.

3.4 Determination of water activity

The water activity or relative vapour pressure is an essential parameter to the quality and stability of the food product [23]. It is displayed through the a_w value, which is always smaller than 1. Higher water activity influences more intense growth of the microorganisms and increased risk of food spoilage.

As shown in Table 5, water activity in the zero-waste and traditionally prepared vegetable spreads was 0.9280 - 0.9420 and there was no significant difference among differently prepared vegetable spreads.

Table 5. Water activity (aw) of the vegetable spreads

Parameters	Water activity, a_w
Carrot ZW	0.9344 ± 0.0032
Carrot TR	0.9386 ± 0.0038
Parsnip ZW	0.9420 ± 0.0035
Parsnip TR	0.9400 ± 0.0292
Beetroot ZW	0.9370 ± 0.0063
Beetroot TR	0.9280 ± 0.0082

The results of Table 5 represent the average and standard deviation of three replicates. There was no statistically significant difference between samples ($p \geq 0.05$).

3.5 Sensory evaluation

As displayed in Table 6, 30 consumers assessed and scored their perception for sensory parameters: appearance, colour, flavour, taste, texture and overall acceptability of the carrot, parsnip and beetroot spreads based on a five-point hedonic scale.

Results of the survey demonstrate, that there is no statistically significant difference between appearance, colour and texture of the zero-waste and traditionally prepared vegetable spreads ($p \geq 0.05$). Instead,

Table 4. Presence of Klebsiella spp. and faecal coliforms (CFU/mL) in the vegetable spreads. The values represent the average of five replicates

Parameters	Faecal coliform count (CFU/mL)	*Klebsiella* spp. (CFU/mL	*Salmonella* spp. (CFU/mL)
Carrot ZW	0	0	0
Carrot TR	0	7.6x10^1	0
Parsnip ZW	0	2.5x10^1	0
Parsnip TR	0	4.3x10^1	0
Beetroot ZW	0	4.68x1^02	0
Beetroot TR	0	6.32x10^2	0

Table 6. Acceptance scores of the vegetable spread

Parameters	Appearance	Colour	Flavour	Texture	Taste	Overall acceptability
Carrot ZW	3.72 ± 0.89	3.92 ± 0.95	3.36 ± 0.99	3.72 ± 0.89	3.36 ± 0.91	3.76 ± 0.97
Carrot TR	4.04 ± 0.73	4.28 ± 0.74	2.72 ± 1.17	3.76 ± 0.83	2.76 ± 0.88	3.2 ± 1.00
Parsnip ZW	4.00 ± 0.65	4.08 ± 0.81	3.00 ± 0.82	2.52 ± 0.87	3.00 ± 0.91	4.2 ± 0.76
Parsnip TR	4.00 ± 0.87	4.00 ± 0.96	2.52 ± 0.77	2.48 ± 1.00	2.24 ± 1.27	3.44 ± 0.87
Beetroot ZW	4.24 ± 0.78	4.32 ± 0.85	3.64 ± 0.95	3.76 ± 0.78	3.92 ± 0.95	4.04 ± 0.98
Beetroot TR	4.20 ± 0.82	4.24 ± 0.88	2.96 ± 1.27	3.60 ± 0.96	3.16 ± 1.03	3.44 ± 1.12

flavour, taste and overall acceptability of the zero-waste vegetable spreads were evaluated better than traditionally prepared vegetable spreads ($p < 0.05$).

Consumers gave the best evaluations for the zero-waste parsnip and beetroot spreads, 4.2 and 4.04 out of five points.

The results of Table 6 represent the average ($n = 30$) and standard deviation value. The data analysis shows that there is no significant difference between appearance, colour and texture of the samples ($p \geq 0.05$).

4. Conclusions

- The results showed that the mineral content, moisture content and calorie content were higher in the zero-waste products ($p < 0.05$), but there was no significant difference in water activity, protein, fat and carbohydrate content ($p \geq 0.05$).
- Determination of *Salmonella* spp., *Klebsiella* spp. and coliform bacteria as well as the total amount of microorganisms shows that the prepared spreads meet food safety standards. The microbiological tests showed that the carrot spreads had a shelf life of 3 and 4 days, including the day of preparation, for the zero-waste and traditional preparation methods, respectively. The two parsnip spread recipes had a shelf life of 5 days. The shelf life of the traditional and the no-waste beetroot spread was 3 days including the day of preparation.
- No-waste cooking method can change the sensory aspect of a product. The carrot spread without waste had a green appearance instead of the classic orange colour. It is sweeter and has a mild aftertaste, whereas traditional carrot spread is tarter and tangier. Zero waste beetroot spread is redder and sweeter than traditionally prepared one. The zero-waste cooking method reduces the strong sour taste of parsnip spread compared to traditional methods.
- In summary, the use of the outer layers and leaves of root vegetables has a positive impact on the mineral, moisture and caloric content of vegetable spreads is microbiologically safe, and appeals to the consumer's senses.

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