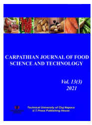

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DETERMINATION OF NUTRITIONAL AND MINERAL COMPOSITION OF WASTED PEELS FROM GARLIC, ONION AND POTATO

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ABSTRACT

In this research, the results of determining the nutritional and mineral composition of garlic, onion and potato wasted peels were presented. It was found that garlic wasted peels were characterized by the highest content of total dietary fibre (62.10%), total sugars (6.51%), dry matter (80.8%), total ash (7.37%), B (18.0 mg/kg), Al (826 mg/kg), S (1635 mg/kg), K (9081 mg/kg), Ca (20610 mg/kg), Cr (18.40 mg/kg), Mn (35.4 mg/kg), Fe (682 mg/kg), Zn (12.9 mg/kg), Se (0.058 mg/kg) and Mo (1.480 mg/kg). Onion wasted peels were the richest in free fat (0.31%), reducing sugars (3.10%), Na (1021 mg/kg), Mg (1285 mg/kg), P (881 mg/kg) and Cu (4.58 mg/kg). Potato wasted peels contained the highest amount of crude protein (2.67%), digestible carbohydrates (9.5%) and water content (84.3%). The waste materials that were investigated could be used as a source to obtain valuable components presented in large quantities in them.

1.Introduction

Fruit and vegetable peel wastes are commonly generated from both households and food processing industry (Pathak et al., 2016). Unavoidable food supply chain wastes represent a perspective waste as a resource due to its high volume, chemical richness and heterogeneity (Matharu et al., 2016). According to Bhatnagar et al. (2015), agricultural waste materials are economic and environmental friendly due to their chemical composition and their availability in abundance. Waste peels from fruits and vegetables are of great importance as a renewable resource and an agro-industrial waste. Fruits and vegetables wastes and by-products, including peels, which are generated in high amounts during industrial processing, represent a serious environmental problem and need to be managed and utilized. Efforts have been made to improve methods and ways of reusing fruits and vegetables wastes. Agro industrial waste often is utilized as feed or fertilizer. Valorizing the biocomponents in by-products from fruit and vegetable industries is perspective and important way of reusing these waste materials (Bhatnagar et al., 2015).

Hameed and Ahmad (2009) investigated the potential of garlic peel, agricultural waste, for the removal of methylene blue from aqueous solution (Hameed and Ahmad, 2009). Prasad Reddy and Rhim (2014) extracted cellulose micro-fibres and cellulose nanocrystals from garlic skins – underutilized agricultural by-products (Prasad Reddy and Rhim, 2014). Chhouk et al. (2017) used carbon dioxide expanded ethanol method to extract phenolic compounds from garlic husk, which was regarded as agricultural waste (Chhouk et al., 2017). Huang G.-g. et al. (2019) used garlic peel as the precursor for carbons via hydrothermal carbonization and KOH activation for CO_2 adsorption (Huang G.-g. et al., 2019).

Ng et al. (1999) studied the effects of extrusion-cooking on the physico-chemical parameters and microstructure of cell walls of onion waste (Ng et al., 1999). Coventry et al. (2002) showed the potential of composted onion waste for decreasing the inoculum density of soil infested with *Sclerotium cepivorum* on a small-scale basis (Coventry et al., 2002). Roldán et al. (2008) studied bioactive, antioxidant and antibrowning properties of onion by-products stabilized by different treatments (Roldán et al., 2008). In the study by Kiassos et al. (2009), response surface methodology was implemented in order to optimize recovery of polyphenols from onion solid wastes (Kiassos et al., 2009). In their work, Moussouni et al. (2010) presented the use of a crude peroxidase homogenate from onion solid waste as a biocatalyst for the synthesis of the natural aurone, aureusidin (Moussouni et al., 2010). According to Albishi et al. (2013), onion skin may serve as a promising source of natural antioxidants for the development of food systems or value-added products (Albishi et al., 2013). Angeleska et al. (2013) studied the biocatalytic activity of a crude peroxidase extract from onion solid waste on the reaction between catechol and heterocyclic 1,3-dicarbonyl compounds (Angeleska et al., 2013). Choi et al. (2015) studied the potential of enzymatic hydrolysis for glucose production and quercetin extraction from onion skin waste (Choi et al., 2015). In their study, Katsampa et al. (2015) used onion solid wastes as a source to produce antioxidant polyphenol- and pigment-enriched extracts by ultrasound-assisted solid-liquid extraction (Katsampa et al., 2015). Benítez et al. (2017) obtained fibre concentrates from onion by-products, studied their effects on glucose adsorption, as well as their composition, physicochemical properties, alpha-amylase activity and starch digestibility (Benítez et al., 2017). Nile S.H. et al. (2017) reported a significant amount of quercetin and quercetin glycosides in onion solid waste with antioxidant and enzyme inhibitory activities against urease and xanthine oxidase (Nile S.H. et al., 2017). Kim H.M. et al. (2017) investigated the production of valuable rare sugars and bioethanol from onion juice residue for efficient use the waste material (Kim H.M. et al., 2017). According to Maiti et al. (2017), naturally abundant bio-waste onion skins could be a promising bio-piezoelectric material for harvesting green energy from mechanical and biomechanical activities (Maiti et al., 2017). The results of work by Nile A. et al. (2018) indicated that onion solid waste and the extracted flavonols had potential beneficial effects (Nile A. et al., 2018). Munir et al. (2018) used subcritical water extraction to recover bioactive phenolic compounds from waste onion skin (Munir et al., 2018). Baldassarre et al. (2018) valorized onion skins (an under-utilized agricultural by-product) towards enzymatic pectic oligosaccharides production with high hydrolysis performance (Baldassarre et al., 2018). Campone et al. (2018) developed a green analytical procedure for the analysis of phenolic compounds in outer dry layers of brown skin onion (Campone et al., 2018). Kim S.-W. et al. (2019) developed an emerging hurdle technology for maximizing extraction efficiency of quercetin from onion waste (Kim S.-W. et al., 2019). According to Mondal et al. (2019), onion peel dust can be effectively utilized as an adsorbent for the removal of nitrate from aqueous solutions (Mondal et al., 2019). Alonso-Lemus et al. (2019) prepared non-noble metal electrocatalysts from onion skin wastes (Alonso-Lemus et al., 2019).

Madhumithah et al. (2011) studied the utilization of vegetable wastes, including potato wastes, for the production of protease by *Aspergillus niger* (Madhumithah et al., 2011). In the study by Hossain M.B. et al. (2014), steroidal alkaloids were extracted from potato peel waste by ultrasound assisted extraction and solid liquid extraction (Hossain M.B. et al., 2014). Hossain M.B. et al. (2015) optimized solvent concentration and temperature for recovery of steroidal alkaloids from potato peels using pressurized liquid extraction assisted by response surface methodology (Hossain M.B. et al., 2015). Lappalainen et al. (2015) modified the starch-containing biomaterial potato peel waste by alkaline hydrolysis and cationization like native starch (Lappalainen et al., 2015). Liang et al. (2015) produced lactic acid by anaerobic fermentation of potato peel waste in a sequencing batch reactor inoculated with undefined mixed culture from a municipal wastewater treatment plant (Liang et al., 2015). Liang and McDonald (2015) studied the feasibility of biogas production from potato peel waste and its lactic acid fermentation residue in a batch anaerobic digestion process under mesophilic condition (Liang and McDonald, 2015). In the work by Jacob and Banerjee (2016), an aquatic weed *Pistia stratiotes* has been established as an efficient co-substrate for industrial potato waste (Jacob and Banerjee, 2016). Chintagunta et al. (2016) produced ethanol in short incubation time by employing co-culture of *Aspergillus niger* and *Saccharomyces cerevisiae* to potato waste through simultaneous saccharification and fermentation, and investigated the possibilities of utilizing the residue after ethanol fermentation for further enrichment as biomanure (Chintagunta et al., 2016). In their work, Du and Li (2016) demonstrated the capability of microbial fuel cell in simultaneous potato waste reduction and electricity generation as well as the significant effects of mixed treatment with cooked potato (Du and Li, 2016). In another their work, Du and Li (2017) showed the effect of mixed feeding of anaerobically cultured waste activated sludge on the performance of microbial fuel cell for direct treatment of solid potato waste (Du and Li, 2017). Kumar et al. (2016) developed a microwave irradiation based process using a solid acid catalyst for the production of glucose from potato peel waste (Kumar et al., 2016). According to Gupta et al. (2016), potato plant wastes can be an adsorbent for the removal of cationic dyes (methylene blue and malachite green) from aqueous solution (Gupta et al., 2016).

Abdelraof et al. (2019) investigated the bacterial cellulose production by using potato peel waste hydrolysate by green environmental friendly method (Abdelraof et al., 2019). According to Ben Atitallah et al. (2019), potato peels waste is an attractive by-product to produce bioethanol using a newly isolated yeast strain *Wickerhamomyces anomalus* (Ben Atitallah et al., 2019). Chohan et al. (2020) optimized bioethanol production from potato peel waste using simultaneous saccharification and fermentation process (Chohan et al., 2020). In the work by Ghinea et al. (2019), the physico-chemical characteristics of fruit and vegetable waste, including potatoes, were determined in order to develop a model for food waste composting (Ghinea et al. 2019). Li et al. (2019) evaluated the possibility and controlling strategy of acidogenic fermentation of wasted potato at different pH values (Li et al., 2019). Yang J.-S. et al. (2019) used ultrasound-microwave assisted extraction combined with HCl for extraction of pectin from potato pulp by response surface methodology (Yang J.-S. et al., 2019). Zhang Y. et al. (2019a) studied the feasibility of potato processing waste as a co-substrate for co-digestion with microalgae *Chlorella vulgaris* in batch biochemical methane potential tests (Zhang Y. et al., 2019a). Zhang Y. et al. (2019b) investigated the feasibility of using potato processing waste as a feedstock for co-digestion with a marine microalgae (*Tisochrysis lutea*) during semi-continuous anaerobic study (Zhang Y. et al., 2019b).

In the work by Díaz et al. (2017), vegetable supermarket wastes, including potatoes, have been treated by acid, thermal and enzymatic hydrolisis procedures with the purpose to maximise the concentration of fermentable sugars in the final broth (Díaz et al., 2017). Mu et al. (2017) used anaerobic granular sludge as an inoculum for co-digestion of potato waste and cabbage waste in batch and semi-continuous mesophilic modes for enhanced methane production (Mu et al., 2017). Rodríguez Amado et al. (2014) optimized the extraction of antioxidants from potato peel waste by three variables (processing-time, temperature and ethanol concentration) (Rodríguez Amado et al., 2014). In their work, Vázquez and Guerra Rodríguez (2011) elucidated using computer simulation if the biotechnological production of transglutaminase by *Streptomyces mobaraensis* from hydrolysates of potato wastes is feasible (Vázquez and Guerra Rodríguez, 2011). Zhang Z. et al. (2015) prepared activated carbon (a low cost and highly efficient adsorbent) from waste potato residue (Zhang Z. et al., 2015). Wei et al. (2015) prepared green biocomposites from polyhydroxybutyrate and potato peel waste fermentation residue fibres (low-value waste byproduct from a fermentation process of potato peel waste) and studied the potential applications of the potato peel waste fermentation residue fibres in agriculture and horticulture as biocomposites (Wei et al., 2015). Wijngaard et al. (2012) optimized the solid-liquid extraction and pressurized liquid extraction of antioxidant from industrial potato peel waste by response surface methodology (Wijngaard et al., 2012). In the review by Wu (2016), several advanced potato peel processing technologies were introduced, their advantages and disadvantages were analyzed from the standpoint of popularization and economy (Wu, 2016). Riciputi et al. (2018) determined the phenolic contents in industrial potato by-products obtained after potato processing by using response surface methodology (Riciputi et al., 2018). Xie et al. (2018) investigated the structural characteristics, physicochemical properties and morphology of pectin from potato peel waste treated with high hydrostatic pressure and high pressure homogenization (Xie et al., 2018). Yang X. et al. (2018) prepared a novel biochar with a microscale spherical shape from the zero-cost feedstock, potato peel waste, via a two-step thermal process (Yang X. et al., 2018).

The main objective of the present work is determination of nutritional and mineral composition of wasted peels from garlic, onion and potato. This would be useful in further investigations to look for opportunities to utilize these waste materials.

2. Materials and methods

2.1. Materials

In this research, wasted peels from garlic, onion and potato were used as tested material. The samples were collected from the local market and were examined in the SGS Bulgaria Ltd, Laboratory Varna. Garlic, onion and potato wasted peels were analyzed for the following parameters: free fat, crude protein, total dietary fibre, digestible carbohydrates, total sugars, reducing sugars, water content, dry matter, total ash, mineral composition.

2.2. Methods

2.2.1. Determination of free fat

The method for determining free fat is based on the extraction of fat from the product with an organic solvent (petroleum ether) in a Soxle apparatus, evaporation of the solvent and weight determination of the mass of the extracted fat.

2.2.2. Determination of crude protein

The test is carried out by the Kjeldhal method – mineralization of the sample with concentrated sulfuric acid at a temperature of 420ºC (the organic-bound nitrogen is mineralized to ammonium ion), alkalization and distillation of the liberated ammonia in boric acid solution, titrimetric determination of distilled ammonia with hydrochloric acid, calculating the protein content of ammonia quantity at a factor of N=6.25.

2.2.3. Determination of total dietary fibre

The sample is gelatinized with α-amylase, the proteins are digested with protease and the starch is digested with amyloglucosidase. Dietary fibre is precipitated with ethanol. They are separated by vacuum filtration and degreased. The sample is dried and the fibres are determined by weight. The result is adjusted for protein and ash.

2.2.4. Determination of carbohydrates (digestible)

Determination of digestible carbohydrates is performed by calculation method. Analytical data are required for all other nutritional components of the product concerned – water content, protein, fat content, total ash, total dietary fibre. Carbohydrate content is calculated as a percentage of the total mass.

2.2.5. Determination of reducing sugars

The principle of the method for determining of reducing sugars consists in the quantitative reduction of the Cu^{2+} contained in the Luff solution, from the reducing sugars in the product to the Cu^{1+} and the oxidation of the latter by iodine solution and residual titration of iodine with sodium thiosulphate solution.

2.2.6. Determination of total sugars

Total sugars are determined by the algorithm of reducing sugars after conversion of sucrose to reducing sugars with hydrochloric acid.

2.2.7. Determination of water content

The water content is determined by azeotropic distillation – the sample was boiled in toluene, the separated water vapor condensed in a refrigerator and captured in a graduated receiver. The process continues until the water is completely separated. The water content is calculated from the reported amount of water taken away from the mass of the sample.

2.2.8. Determination of dry matter

The amount of dry matter is calculated after azeotropically determining of the water content.

2.2.9. Determination of total ash

Determination of total ash involves complete ash of the sample at 500-550ºC and weight determination of the ash content.

2.2.10. Determination of mineral composition

The sample is mineralized with a mixture of nitric acid and hydrogen peroxide (or hydrochloric acid), under pressure or by incineration in a muffle furnace at 450ºC. After decomposition, the sample solution is adjusted to the correct volume and the content of metals and non-metals is determined directly by ICP-OES/ICP-MS.

Methodologies well-described in details could be also found in the work by Baloch et al. (2015).

3.Results and discussions

3.1. Nutritional composition of garlic, onion and potato wasted peels

In Table 1, the results for the nutritional composition of garlic, onion and potato wasted peels were presented. The free fat content was highest in onion wasted peels (0.31%), followed by garlic wasted peels (0.22%) and potato wasted peels (0.15%). The crude protein content was similar in garlic wasted peels (2.61%) and potato wasted peels (2.67%). The crude protein content was lower in onion wasted peels (1.92%) than in wasted peels from garlic and potato. The amount of total dietary fiber was significantly higher in garlic wasted peels (62.10%) than in onion wasted peels (16.02%) and potato wasted peels (2.53%). Digestible carbohydrates predominated in potato wasted peels (9.5%), followed by garlic wasted peels (8.5%) and onion wasted peels (4.7%).

Table 1. Nutritional composition of wasted peels from garlic, onion and potato

Parameter, %	Garlic wasted peels	Onion wasted peels	Potato wasted peels
Free fat	0.22 ± 0.01	0.31 ± 0.02	0.15 ± 0.01
Crude protein	2.61 ± 0.15	1.92 ± 0.15	2.67 ± 0.15
Total dietary fibre	62.10 ± 3.11	16.02 ± 0.80	2.53 ± 0.25
Carbohydrates (digestible)	8.5 ± 1.7	4.7 ± 0.9	9.5 ± 1.9
Sugars (total)	6.51 ± 0.25	4.29 ± 0.25	1.68 ± 0.25
Sugars (reducing)	1.36 ± 0.25	3.10 ± 0.25	0.53 ± 0.06
Water content	19.2 ± 0.3	75.3 ± 0.3	84.3 ± 0.3
Dry matter	80.8 ± 0.3	24.8 ± 0.3	15.8 ± 0.3
Total ash	7.37 ± 0.22	1.71 ± 0.05	0.88 ± 0.03

The richest in total sugars were garlic wasted peels (6.51%), followed by onion wasted peels (4.29%) and potato wasted peels (1.68%). The amount of reducing sugars was highest in onion wasted peels (3.10%), followed by garlic wasted peels (1.36%) and potato wasted peels (0.53%).

The richest in water content were potato wasted peels (84.3%), followed by onion wasted peels (75.3%) and garlic wasted peels (19.2%). The highest dry matter content was found in garlic wasted peels (80.8%), followed by onion wasted peels (24.8%) and potato wasted peels (15.8%). Garlic wasted peels were the richest in total ash (7.37%), followed by onion wasted peels (1.71%) and potato wasted peels (0.88%).

Compared to our results for garlic wasted peels, Pathak et al. (2016) obtained 5.84% moisture and 8.47% ash content in garlic peels (Pathak et al., 2016).

According to Kallel et al. (2014), garlic husks can be used as an easily accessible source of natural bioactive compounds. Kallel et al. (2014) obtained 3.52 g/100g moisture, 16.65 g/100g ash, 8.43 g/100g protein, 0.86 g/100g lipid, 62.23 g/100g total dietary fibre content in garlic husk (Kallel et al., 2014).

Onion wastes include onion skins, outer fleshy scales and roots generated during industrial peeling, as well as undersized, malformed, diseased or damaged bulbs (Benítez et al., 2011). According to Salak et al. (2013), subcritical water treatment can be used to potentially solubilize and hydrolyze onion waste (a low cost feedstock) into valuable compounds. The conversion and solubility of carbohydrates were increased by this method (Salak et al., 2013).

Benítez et al. (2011) obtained the following values for the chemical composition of industrial onion wastes from two cultivars: in outer scales (6.3% and 7.5% dry matter; 9.3% and 8.3% crude protein; 5.6% and 4.6% total ash), in top-bottom (13.2% and 18.0% dry matter; 15.6% and 15.0% crude protein; 8.6% and 8.2% total ash), and in brown skin (51.9% and 50.8% dry matter; 2.3% and 2.4% crude protein; 10.6% and 9.3% total ash) (Benítez et al., 2011).

According to Pereira et al. (2017), dried onion waste had 9.41% moisture content, 1.48% ash, 36.56% reducing sugars (Pereira et al., 2017).

Unlike our results (Table 1), Mukherjee et al. (2008) obtained the following values for the proximate composition of potato peel in terms of crude protein (16.72%), crude lipid (0.6%), crude fibre (7.8%), ash (7.0%) (Mukherjee et al., 2008).

Sharoba et al. (2013) obtained lower moisture content (3.58%), higher total ash content (6.92%), higher fat content (2.25%), higher protein content (12.16%) and higher total dietary fibre content (73.25%) in potato peels (Sharoba et al., 2013) compared to our results (Table 1).

Our results for potato wasted peels (Table 1) were lower than results obtained by Liang et al. (2015) for chemical composition of potato peel waste from two different potato processing plants: carbohydrate content (39.9% and 51.3%), protein (22.4% and 22.8%), lipids (2.6% and 2.1%), ash (8.5% and 11.0%) (Liang et al., 2015).

Liang and McDonald (2015) obtained 39.3% carbohydrates and 2.0% lipids content in potato peel waste (Liang and McDonald, 2015). These values were higher than results obtained by us (Table 1).

Ravi et al. (2018) obtained the following nutritional values of potato waste: water (6.00%), crude ash (6.30%), crude protein (10.45%), crude fat (0.62%), crude fibre (2.50%) (Ravi et al., 2018).

The value of dry matter of potato wasted peel (15.8%) (Table 1) was very similar to the value of dry matter content in potato peel (16.3%) obtained by Hossain M.E. et al. (2015). According to Hossain M.E. et al. (2015), potato peel was characterized with 13.0% crude protein, 12.5% crude fibre, 9.0% ash (Hossain M.E. et al., 2015).

According to Jacob et al. (2016), potato wastes characterized with 84% moisture, 10%

ash, 43% carbohydrate, 8.75% protein content (Jacob et al., 2016).

3.2. Mineral composition of garlic, onion and potato wasted peels

The results for the mineral composition of garlic, onion and potato wasted peels were presented in Table 2.

In terms of mineral composition, the highest calcium content was found in garlic wasted peels (20610 mg/kg). The second content element in garlic wasted peels was potassium (9081 mg/kg). In onion wasted peels, the highest was the calcium content (5134 mg/kg), followed by potassium (2918 mg/kg).

Potassium content predominated in potato wasted peels (4959 mg/kg). The calcium content of potato wasted peels (130 mg/kg) was significantly lower than that of wasted peels from garlic and onion. The richest in sulfur were garlic wasted peels (1635 mg/kg), followed by onion wasted peels (1172 mg/kg) and potato wasted peels (390 mg/kg). The richest in magnesium were onion wasted peels (1285 mg/kg), followed by garlic wasted peels (950 mg/kg) and potato wasted peels (325 mg/kg).

Table 2. Mineral composition of wasted peels from garlic, onion and potato

Parameter, mg/kg	Garlic wasted peels	Onion wasted peels	Potato wasted peels
B	18.0 ± 10 rel.%	7.75 ± 10 rel.%	1.21 ± 10 rel.%
Na	123 ± 5 rel.%	1021 ± 5 rel.%	17.6 ± 10 rel.%
Mg	950 ± 5 rel.%	1285 ± 5 rel.%	325 ± 5 rel.%
Al	826 ± 5 rel.%	23.8 ± 10 rel.%	62.7 ± 10 rel.%
P	721 ± 5 rel.%	881 ± 5 rel.%	378 ± 5 rel.%
S	1635 ± 5 rel.%	1172 ± 5 rel.%	390 ± 5 rel.%
K	9081 ± 5 rel.%	2918 ± 5 rel.%	4959 ± 5 rel.%
Ca	20610 ± 5 rel.%	5134 ± 5 rel.%	130 ± 5 rel.%
Cr	18.40 ± 10 rel.%	0.990 ± 15 rel.%	<0.050
Mn	35.4 ± 10 rel.%	7.23 ± 10 rel.%	2.03 ± 10 rel.%
Fe	682 ± 5 rel.%	36.7 ± 10 rel.%	41.6 ± 10 rel.%
Cu	2.09 ± 10 rel.%	4.58 ± 10 rel.%	1.67 ± 10 rel.%
Zn	12.9 ± 10 rel.%	11.7 ± 10 rel.%	4.32 ± 10 rel.%
Se	0.058 ± 20 rel.%	<0.050	<0.050
Mo	1.480 ± 10 rel.%	0.470 ± 15 rel.%	<0.050

Sodium content was significantly higher in onion wasted peels (1021 mg/kg) than in wasted peels from garlic (123 mg/kg) and potato (17.6 mg/kg). Aluminum content was much more prevalent in garlic wasted peels (826 mg/kg) compared to potato wasted peels (62.7 mg/kg) and onion wasted peels (23.8 mg/kg).

Wasted peels from onion were the most abundant in phosphorus (881 mg/kg), followed by garlic wasted peels (721 mg/kg) and potato wasted peels (378 mg/kg). The richest in boron were garlic wasted peels (18.0 mg/kg), followed by onion wasted peels (7.75 mg/kg) and potato wasted peels (1.21 mg/kg).

A significant difference was found in the chromium content. While garlic wasted peels contained 18.40 mg/kg chromium, onion wasted peels contained only 0.990 mg/kg chromium, and in potato wasted peels, chromium content was below the detectable minimum (<0.050 mg/kg).

Garlic wasted peels were the richest in manganese (35.4 mg/kg) compared to wasted peels from onion (7.23 mg/kg) and potato (2.03 mg/kg). Iron content was the highest in garlic wasted peels (682 mg/kg), followed by potato wasted peels (41.6 mg/kg) and onion wasted peels (36.7 mg/kg).

The copper content predominated in onion wasted peels (4.58 mg/kg), followed by garlic wasted peels (2.09 mg/kg) and potato wasted peels (1.67 mg/kg). The zinc content of wasted peels from garlic and onion was 12.9 mg/kg and 11.7 mg/kg, respectively, and 4.32 mg/kg in potato wasted peels.

Very low selenium content was found in garlic wasted peels (0.058 mg/kg), while in wasted peels from onion and potato, selenium content was below the detectable minimum (<0.050 mg/kg). In wasted peels from garlic and onion, molybdenum content was found to be 1.480 mg/kg and 0.470 mg/kg, respectively, while in potato wasted peels molybdenum was below the detectable minimum (<0.050 mg/kg).

The results we found showed that the content of the first five elements in wasted peels from onion and potato decreased in the following order: Ca>K>Mg>S>Na and K>S>P>Mg>Ca, respectively (Table 2). The results we obtained differed from those obtained by Asquer et al. (2013), Khattak and Rahman (2017) and Kuppusamy et al. (2017).

According to Asquer et al. (2013), the first five minerals in onion wastes, sorted by decreasing amount, were as follows: K>Ca>Mg>Na>Zn, and in potato wastes: K>Ca>Al>Mg>Zn (Asquer et al., 2013). According to Khattak and Rahman (2017), the content of the first five minerals in potato peels decreased as follows: K>P>Na>Mg>Ca (Khattak and Rahman, 2017).

According to Kuppusamy et al. (2017), the elements P, K, Ca, Mg, S, Na decreased in the following order in onion peels and in potato peels, respectively: Ca>Na>Mg>K>S>P and K>Na>P>S>Ca=Mg (Kuppusamy et al., 2017).

According to Benítez et al. (2011), the amounts of minerals they studied in industrial onion wastes from two cultivars decreased as follows: in outer scales (Zn>Fe>K>Mn>Ca>Mg>Se and Fe>Zn>K>Mn>Ca>Mg>Se), in top-bottom (Fe>Zn>Mn>Ca>K>Mg>Se and Fe>Zn>Mn>K>Ca>Mg>Se), and in brown skin (Fe>Ca>Zn>Mn>K>Mg>Se and Fe>Mn>Ca>Zn>K>Mg>Se) (Benítez et al., 2011).

According to Kallel et al. (2014), the mineral content in garlic husk decreased in the following order: Ca>K>Na>Mg>Fe>Mn>Zn>Cu (Kallel et al., 2014).

4. Conclusions

The results obtained in this study showed that in terms of nutritional composition garlic wasted peels were characterized by the highest content of total dietary fibre (62.10%), total sugars (6.51%), dry matter (80.8%), total ash (7.37%). Onion wasted peels were the richest in free fat (0.31%) and reducing sugars (3.10%). Potato wasted peels contained the highest amount of crude protein (2.67%), digestible carbohydrates (9.5%) and water content (84.3%). In garlic wasted peels, the content of the elements decreased in the following order: Ca (20610 mg/kg), K (9081 mg/kg), S (1635 mg/kg), Mg (950 mg/kg), Al (826 mg/kg), P (721 mg/kg), Fe (682 mg/kg), Na (123 mg/kg), Mn (35.4 mg/kg), Cr (18.40 mg/kg), B (18.0 mg/kg), Zn (12.9 mg/kg), Cu (2.09 mg/kg), Mo (1.480 mg/kg) and Se (0.058 mg/kg). In onion wasted peels, the content of the elements decreased as follows: Ca (5134 mg/kg), K (2918 mg/kg), Mg (1285 mg/kg), S (1172 mg/kg), Na (1021 mg/kg), P (881 mg/kg), Fe (36.7 mg/kg), Al (23.8 mg/kg), Zn (11.7 mg/kg), B (7.75 mg/kg), Mn (7.23 mg/kg), Cu (4.58 mg/kg), Mo (0.470 mg/kg). The content of Se in onion wasted peels was below the detectable minimum (<0.050 mg/kg). In potato wasted peels, the content of the elements decreased in the following order: K (4959 mg/kg), S (390 mg/kg), P (378 mg/kg), Mg (325 mg/kg), Ca (130 mg/kg), Al (62.7 mg/kg), Fe (41.6 mg/kg), Na (17.6 mg/kg), Zn (4.32 mg/kg), Mn (2.03 mg/kg), Cu (1.67 mg/kg), B (1.21 mg/kg). The contents of Cr, Se and Mo in potato wasted peels were below the detectable minimum (<0.050 mg/kg). The waste materials that were researched in this work could be used as a source to obtain valuable components presented in large quantities in them.

5.References

Abdelraof, M., Hasanin, M.S., El-Saied, H. (2019). Ecofriendly green conversion of potato peel wastes to high productivity bacterial cellulose. *Carbohydrate Polymers*, 211, 75-83.

Albishi, T., John, J.A., Al-Khalifa, A.S., Shahidi, F. (2013). Antioxidative phenolic constituents of skins of onion varieties and their activities. *Journal of Functional Foods*, 5, 1191-1203.

Alonso-Lemus, I.L., Escobar-Morales, B., Lardizabal-Gutierrez, D., de la Torre-Saenz, L., Quintana-Owen, P., Rodriguez-Varela, F.J. (2019). Short communication: Onion skin waste-derived biocarbon as alternative non-noble metal electrocatalyst towards ORR in alkaline media. *International Journal of Hydrogen Energy*, 44, 12409-12414.

Angeleska, S., Kefalas, P., Detsi, A. (2013). Crude peroxidase from onion solid waste as a tool for organic synthesis. Part III: synthesis of tetracyclic heterocycles (coumestans and benzofuroquinolinones). *Tetrahedron Letters*, 54, 2325-2328.

Asquer, C., Pistis, A., Scano, E.A. (2013). Characterization of fruit and vegetable wastes as a single substrate for the anaerobic digestion. *Environmental Engineering and Management Journal*, 12(S11), 89-92.

Baldassarre, S., Babbar, N., Van Roy, S., Dejonghe, W., Maesen, M., Sforza, S., Elst, K. (2018). Continuous production of pectic oligosaccharides from onion skins with an enzyme membrane reactor. *Food Chemistry*, 267, 101-110.

Baloch, A.B., Xia, X., Sheikh, S.A. (2015). Proximate and mineral compositions of dried cauliflower (Brassica Oleracea L.) grown in Sindh, Pakistan. *Journal of Food and Nutrition Research*, 3(3), 213-219.

Ben Atitallah, I., Antonopoulou, G., Ntaikou, I., Alexandropoulou, M., Nasri, M., Mechichi, T., Lyberatos, G. (2019). On the evaluation of different saccharification schemes for enhanced bioethanol production from potato peels waste via a newly isolated yeast strain of *Wickerhamomyces anomalus*. *Bioresource Technology*, 289, 121614.

Benítez, V., Mollá, E., Martín-Cabrejas, M.A., Aguilera, Y., López-Andréu, F.J., Cools, K., Terry, L.A., Esteban, R.M. (2011). Characterization of industrial onion wastes (*Allium cepa* L.): dietary fibre and bioactive compounds. *Plant Foods for Human Nutrition*, 66(1), 48-57.

Benítez, V., Mollá, E., Martín-Cabrejas, M.A., Aguilera, Y., Esteban, R.M. (2017). Physicochemical properties and *in vitro* antidiabetic potential of fibre concentrates from onion by-products. *Journal of Functional Foods*, 36, 34-42.

Bhatnagar, A., Sillanpää, M., Witek-Krowiak, A. (2015). Agricultural waste peels as versatile biomass for water purification – A review. *Chemical Engineering Journal*, 270, 244-271.

Campone, L., Celano, R., Piccinelli, A.L., Pagano, I., Carabetta, S., Di Sanzo, R., Russo, M., Ibañez, E., Cifuentes, A., Rastrelli, L. (2018). Response surface methodology to optimize supercritical carbon dioxide/cosolvent extraction of brown onion skin by-product as source of nutraceutical compounds. *Food Chemistry*, 269, 495-502.

Chhouk, K., Uemori, C., Wahyudiono, Kanda, H., Goto, M. (2017). Extraction of phenolic compounds and antioxidant activity from garlic husk using carbon dioxide expanded ethanol. *Chemical Engineering & Processing: Process Intensification*, 117, 113-119.

Chintagunta, A.D., Jacob, S., Banerjee, R. (2016). Integrated bioethanol and biomanure production from potato waste. *Waste Management*, 49, 320-325.

Chohan, N.A., Aruwajoye, G.S., Sewsynker-Sukai, Y., Gueguim Kana, E.B. (2020). Valorisation of potato peel wastes for bioethanol production using simultaneous saccharification and fermentation: Process optimization and kinetic assessment. *Renewable Energy*, 146, 1031-1040.

Choi, I.S., Cho, E.J., Moon, J.-H., Bae, H.-J. (2015). Onion skin waste as a valorization resource for the by-products quercetin and biosugar. *Food Chemistry*, 188, 537-542.

Coventry, E., Noble, R., Mead, A., Whipps, J.M. (2002). Control of *Allium* white rot (*Sclerotium cepivorum*) with composted onion waste. *Soil Biology and Biochemistry*, 34(7), 1037-1045.

Díaz, A.I., Laca, A., Laca, A., Díaz, M. (2017). Treatment of supermarket vegetable wastes to be used as alternative substrates in bioprocesses. *Waste Management*, 67, 59-66.

Du, H., Li, F. (2016). Effects of varying the ratio of cooked to uncooked potato on the microbial fuel cell treatment of common potato waste. *Science of the Total Environment*, 569-570, 841-849.

Du, H., Li, F. (2017). Enhancement of solid potato waste treatment by microbial fuel cell with mixed feeding of waste activated sludge. *Journal of Cleaner Production*, 143, 336-344.

Ghinea, C., Apostol, L.C., Prisacaru, A.E., Leahu, A. (2019). Development of a model for food waste composting. *Environmental Science and Pollution Research*, 26, 4056-4069.

Gupta, N., Kushwaha, A.K., Chattopadhyaya, M.C. (2016). Application of potato (*Solanum tuberosum*) plant wastes for the removal of methylene blue and malachite green dye from aqueous solution. *Arabian Journal of Chemistry*, 9, S707-S716.

Hameed, B.H., Ahmad, A.A. (2009). Batch adsorption of methylene blue from aqueous solution by garlic peel, an agricultural waste biomass. *Journal of Hazardous Materials*, 164, 870-875.

Hossain, M.B., Tiwari, B.K., Gangopadhyay, N., O'Donnell, C.P., Brunton, N.P., Rai, D.K. (2014). Ultrasonic extraction of steroidal alkaloids from potato peel waste. *Ultrasonics Sonochemistry*, 21, 1470-1476.

Hossain, M.B., Rawson, A., Aguiló-Aguayo, I., Brunton, N.P., Rai, D.K. (2015). Recovery of steroidal alkaloids from potato peels using pressurized liquid extraction. *Molecules*, 20, 8560-8573.

Hossain, M.E., Sultana, S.A., Karim, M.H., Ahmed, M.I. (2015). Vegetable peels: a promising feed resource for livestock. *Online Journal of Animal and Feed Research*, 5, 33-39.

Huang, G.-g., Liu, Y.-f., Wu, X.-x., Cai, J.-j. (2019). Activated carbons prepared by the KOH activation of a hydrochar from garlic peel and their CO_2 adsorption performance. *New Carbon Materials*, 34(3), 247-257.

Jacob, S., Banerjee, R. (2016). Modeling and optimization of anaerobic codigestion of potato waste and aquatic weed by response surface methodology and artificial neural network coupled genetic algorithm. *Bioresource Technology*, 214, 386-395.

Jacob, S., Chintagunta, A.D., Banerjee, R. (2016). Selective digestion of industrial potato wastes for efficient biomethanation: a sustainable solution for safe environmental disposal. *International Journal of Environmental Science and Technology*, 13, 2363-2374.

Kallel, F., Driss, D., Chaari, F., Belghith, L., Bouaziz, F., Ghorbel, R., Chaabouni, S.E. (2014). Garlic (*Allium sativum* L.) husk waste as a potential source of phenolic compounds: Influence of extracting solvents on its antimicrobial and antioxidant properties. *Industrial Crops and Products*, 62, 34-41.

Katsampa, P., Valsamedou, E., Grigorakis, S., Makris, D.P. (2015). A green ultrasound-assisted extraction process for the recovery of antioxidant polyphenols and pigments from onion solid wastes using Box–Behnken experimental design and kinetics. *Industrial Crops and Products*, 77, 535-543.

Khattak, K.F., Rahman, T.U. (2017). Analysis of vegetable's peels as a natural source of vitamins and minerals. *International Food Research Journal*, 24(1), 292-297.

Kiassos, E., Mylonaki, S., Makris, D.P., Kefalas, P. (2009). Implementation of response surface methodology to optimise extraction of onion (*Allium cepa*) solid waste phenolics. *Innovative Food Science and Emerging Technologies*, 10, 246-252.

Kim, H.M., Song, Y., Wi, S.G., Bae, H.-J. (2017). Production of D-tagatose and bioethanol from onion waste by an intergrating bioprocess. *Journal of Biotechnology*, 260, 84-90.

Kim, S.-W., Ko, M.-J., Chung, M.-S. (2019). Extraction of the flavonol quercetin from onion waste by combined treatment with intense pulsed light and subcritical water extraction. *Journal of Cleaner Production*, 231, 1192-1199.

Kumar, V.B., Pulidindi, I.N., Gedanken, A. (2016). Glucose production from potato peel waste under microwave irradiation. *Journal of Molecular Catalysis A: Chemical*, 417, 163-167.

Kuppusamy, S., Venkateswarlu, K., Megharaj, M. (2017). Evaluation of nineteen food wastes for essential and toxic elements. *International Journal of Recycling of Organic Waste in Agriculture*, 6, 367-373.

Lappalainen, K., Kärkkäinen, J., Joensuu, P., Lajunen, M. (2015). Modification of potato peel waste with base hydrolysis and subsequent cationization. *Carbohydrate Polymers*, 132, 97-103.

Li, Y., Zhang, X., Xu, H., Mu, H., Hua, D., Jin, F., Meng, G. (2019). Acidogenic properties of carbohydrate-rich wasted potato and microbial community analysis: Effect of pH. *Journal of Bioscience and Bioengineering*, 128(1), 50-55.

Liang, S., McDonald, A.G., Coats, E.R. (2015). Lactic acid production from potato peel waste by anaerobic sequencing batch fermentation using undefined mixed culture. *Waste Management*, 45, 51-56.

Liang, S., McDonald, A.G. (2015). Anaerobic digestion of pre-fermented potato peel wastes for methane production. *Waste Management*, 46, 197-200.

Madhumithah, C.G., Krithiga, R., Sundaram, S., Sasikumar, C.S., Guhathakurta, S., Cherian, K.M. (2011). Utilization of vegetable wastes for production of protease by solid state fermentation using *Aspergillus niger*. *World Journal of Agricultural Sciences*, 7(5), 550-555.

Maiti, S., Kumar Karan, S., Lee, J., Kumar Mishra, A., Bhusan Khatua, B., Kon Kim, J. (2017). Bio-waste onion skin as an innovative nature-driven piezoelectric material with high energy conversion efficiency. *Nano Energy*, 42, 282-293.

Matharu, A.S., de Melo, E.M., Houghton, J.A. (2016). Opportunity for high value-added chemicals from food supply chain wastes. *Bioresource Technology*, 215, 123-130.

Mondal, N.K., Ghosh, P., Sen, K., Mondal, A., Debnath, P. (2019). Efficacy of onion peel towards removal of nitrate from aqueous solution and field samples. *Environmental Nanotechnology, Monitoring & Management*, 11, 100222.

Moussouni, S., Detsi, A., Majdalani, M., Makris, D.P., Kefalas, P. (2010). Crude peroxidase from onion solid waste as a tool for organic synthesis. Part I: Cyclization of 2′,3,4,4′,6′-pentahydroxy-chalcone into aureusidin. *Tetrahedron Letters*, 51, 4076-4078.

Mu, H., Zhao, C., Zhao, Y., Li, Y., Hua, D., Zhang, X., Xu, H. (2017). Enhanced methane production by semi-continuous mesophilic co-digestion of potato waste and cabbage waste: Performance and microbial characteristics analysis. *Bioresource Technology*, 236, 68-76.

Mukherjee, A.K., Adhikari, H., Rai, S.K. (2008). Production of alkaline protease by a thermophilic *Bacillus subtilis* under solid-state fermentation (SSF) condition using *Imperata cylindrica* grass and potato peel as low-cost medium: Characterization and application of enzyme in detergent formulation. *Biochemical Engineering Journal*, 39(2), 353-361.

Munir, M.T., Kheirkhah, H., Baroutian, S., Quek, S.Y., Young, B.R. (2018).

Subcritical water extraction of bioactive compounds from waste onion skin. *Journal of Cleaner Production*, 183, 487-494.

Ng, A., Lecain, S., Parker, M.L., Smith, A.C., Waldron, K.W. (1999). Modification of cell-wall polymers of onion waste III. Effect of extrusion-cooking on cell-wall material of outer fleshy tissues. *Carbohydrate Polymers*, 39, 341-349.

Nile, S.H., Nile, A.S., Keum, Y.S., Sharma, K. (2017). Utilization of quercetin and quercetin glycosides from onion (*Allium cepa* L.) solid waste as an antioxidant, urease and xanthine oxidase inhibitors. *Food Chemistry*, 235, 119-126.

Nile, A., Nile, S.H., Kim, D.H., Keum, Y.S., Seok, P.G., Sharma, K. (2018). Valorization of onion solid waste and their flavonols for assessment of cytotoxicity, enzyme inhibitory and antioxidant activities. *Food and Chemical Toxicology*, 119, 281-289.

Pathak, P.D., Mandavgane, S.A., Kulkarni, B.D. (2016). Characterizing fruit and vegetable peels as bioadsorbents. *Current Science*, 110(11), 2114-2123.

Pereira, G.S., Cipriani, M., Wisbeck, E., Souza, O., Strapazzon, J.O., Gern, R.M.M. (2017). Onion juice waste for production of *Pleurotus sajor-caju* and pectinases. *Food and Bioproducts Processing*, 106, 11-18.

Prasad Reddy, J., Rhim, J.-W. (2014). Isolation and characterization of cellulose nanocrystals from garlic skin. *Materials Letters*, 129, 20-23.

Ravi, P.P., Lindner, J., Oechsner, H., Lemmer, A. (2018). Effects of target pH-value on organic acids and methane production in two-stage anaerobic digestion of vegetable waste. *Bioresource Technology*, 247, 96-102.

Riciputi, Y., Diaz-de-Cerio, E., Akyol, H., Capanoglu, E., Cerretani, L., Caboni, M.F., Verardo, V. (2018). Establishment of ultrasound-assisted extraction of phenolic compounds from industrial potato by-products using response surface methodology. *Food Chemistry*, 269, 258-263.

Rodríguez Amado, I., Franco, D., Sánchez, M., Zapata, C., Vázquez, J.A. (2014). Optimisation of antioxidant extraction from *Solanum tuberosum* potato peel waste by surface response methodology. *Food Chemistry*, 165, 290-299.

Roldán, E., Sánchez-Moreno, C., de Ancos, B., Cano, M.P. (2008). Characterisation of onion (*Allium cepa* L.) by-products as food ingredients with antioxidant and antibrowning properties. *Food Chemistry*, 108, 907-916.

Salak, F., Daneshvar, S., Abedi, J., Furukawa, K. (2013). Adding value to onion (*Allium cepa* L.) waste by subcritical water treatment. *Fuel Processing Technology*, 112, 86-92.

Sharoba, A.M., Farrag, M.A., Abd El-Salam, A.M. (2013). Utilization of some fruits and vegetables waste as a source of dietary fiber and its effect on the cake making and its quality attributes. *Journal of Agroalimentary Processes and Technologies*, 19(4), 429-444.

Vázquez, M.V., Guerra Rodríguez, M.E. (2011). Computer simulation of microbial transglutaminase production from potato wastes. *11th International Congress on Engineering and Food (ICEF11). Procedia Food Science*, 1, 736-741.

Wei, L., Liang, S., McDonald, A.G. (2015). Thermophysical properties and biodegradation behavior of green composites made from polyhydroxybutyrate and potato peel waste fermentation residue. *Industrial Crops and Products*, 69, 91-103.

Wijngaard, H.H., Ballay, M., Brunton, N. (2012). The optimisation of extraction of antioxidants from potato peel by pressurised liquids. *Food Chemistry*, 133, 1123-1130.

Wu, D. (2016). Recycle technology for potato peel waste processing: A review. *The Tenth International Conference on Waste Management and Technology (ICWMT).*

Procedia Environmental Sciences, 31, 103-107.

Xie, F., Zhang, W., Lan, X., Gong, S., Wu, J., Wang, Z. (2018). Effects of high hydrostatic pressure and high pressure homogenization processing on characteristics of potato peel waste pectin. *Carbohydrate Polymers*, 196, 474-482.

Yang, J.-S., Mu, T.-H., Ma, M.-M. (2019). Optimization of ultrasound-microwave assisted acid extraction of pectin from potato pulp by response surface methodology and its characterization. *Food Chemistry*, 289, 351-359.

Yang, X., Kwon, E.E., Dou, X., Zhang, M., Kim, K.-H., Tsang, D.C.W., Ok, Y.S. (2018). Fabrication of spherical biochar by a two-step thermal process from waste potato peel. *Science of the Total Environment*, 626, 478-485.

Zhang, Y., Caldwell, G.S., Zealand, A.M., Sallis, P.J. (2019a). Anaerobic co-digestion of microalgae *Chlorella vulgaris* and potato processing waste: Effect of mixing ratio, waste type and substrate to inoculum ratio. *Biochemical Engineering Journal*, 143, 91-100.

Zhang, Y., Caldwell, G.S., Sallis, P.J. (2019b). Semi-continuous anaerobic co-digestion of marine microalgae with potato processing waste for methane production. *Journal of Environmental Chemical Engineering*, 7, 102917.

Zhang, Z., Luo, X., Liu, Y., Zhou, P., Ma, G., Lei, Z., Lei, L. (2015). A low cost and highly efficient adsorbent (activated carbon) prepared from waste potato residue. *Journal of the Taiwan Institute of Chemical Engineers*, 49, 206-211.