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INITIAL TREATMENT, SUBLIMATION DRYING AND STORAGE TIME OF SWEET PEPPER CRISPS. PHYSICO-CHEMICAL QUALITY – PART I

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ABSTRACT

The paper presents the impact of the initial processing, cultivar, and storage time on the physico-chemical quality of freeze-dried crisps. Sweet pepper after initial washing and crushing was subjected to further four combinations of the initial processing. The first combination included freezing, the second one blanching in 98°C and 2-minutes time, the third one -dehydration in 2% solution of ascorbic acid and the fourth one -dehydration in 2% solution of sodium chloride. Both types of dehydration were carried out in 70°C for 20 minutes with a 1:4 participation of raw material to osmotic solution. Blanched and dehydrated raw materials were subjected to freezing in -18°C for 24 hours. After the completed process of freezing, the samples were moved to a freezer-drier and were dried by sublimation in -18°C and the reduced pressure of 63 Pa. Based on the research analyses a significant variability of physico-chemical properties of the obtained freeze-dried sweet pepper with regard to a cultivar, processing type and storage time were reported. Freeze-dried yellow sweet pepper was the most similar to the fresh raw material. It was dehydrated in the ascorbic acid solution. The storage time considerably influenced the reduction of the quality properties of sweet pepper crisps.

Introduction

One of the most important groups of food subjected to thermal preservations are fruit and vegetables. Their processing depends mainly on the seasonal characters and supply of raw material (Kamińska and Lewicki, 2006). Based on the statistical data collected by FAO (Food and Agriculture Organization) the global production of sweet pepper is presently 29,601 million tons. The leading producers of this vegetable in the world are China, Mexico, and Turkey. In 2014, the commodity production of sweet pepper in Poland reached 113 thousand tons. It included harvesting of sweet pepper from crops carried out under roofs which amounted to 90 thousand tons as well field cultures in the amount of 23 thousand tons. Poland, after Holland and Spain takes the third position as a producer of sweet pepper on the

European market (Szwejda-Grzybowska, 2011). Sweet pepper fruit are classified as the second vegetable the most often consumed by consumers in the world (Silvaet et al., 2014). Despite that, its present annual consumption in Poland is still at an extremely low level and is 0.9 kg (Korzeniewska, 2005; Perucka et al., 2010, Perucka and Materska, 2007).

Sweet pepper (*Capsicum annuum* L.) similarly to early potato, tomato or eggplant cultivars comes from a family of *Soleanaceae* (Materska and Perucka, 2005). In many countries, this plant is also known under the names capsicum (Poland), pepper (Great Britain, France, Turkey), bell sweet pepper (Hungary, Germany, Indonesia) and bell pepper (Northern America states) (Surma et al., 2013; Gajc-Wolska and Skąpski, 2002; Markus et al., 1999; Simonne et al., 1997).

A surplus of commodity production of pepper causes that it must be properly processed in order to maintain precious and unstable compounds that are biologically active. One of these methods is its preservation with drying (Shotorbani et al., 2013). Drying is considered to be the most popular method used for food preservation including fruit and vegetables. During this process, many unfavourable changes including degradation of chlorophile and carotenoids and vitamins take place. To protect the colour, it is important to use before drying, a relevant initial processing including, *inter alia*, cutting, blanching, osmotic dehydration, coating with edible coatings (Perera, 2005; Nowacka and Witrowa-Rajchert, 2011).

Sublimation drying (freeze-drying) is considered to be one of the most contemporary and the best methods used for thermal preservation of vegetables and fruit. It enables obtaining a product with a high sensory quality, unchanged and intact shapes, and a high retention of nutrients. Obtaining the quality of the obtained lyophisates does not require any preservatives. Due to high costs of production in case of dried food and high energy inputs, this method is very rarely used. A long-time drying and high costs of installation cause that freeze-drying is the most expensive drying method (Kramkowski, 1997). Production of freeze-dried food in Poland in recent years shows an increasing trend up to 29.7 thousand tons. Usually, drying is used for production of comfortable food instant type (Ciurzyńska and Lenart, 2010).

The aim of the paper was to determine the impact of the initial processing, sweet pepper cultivar, and the storage time on the physico-chemical quality of freeze-dried food.

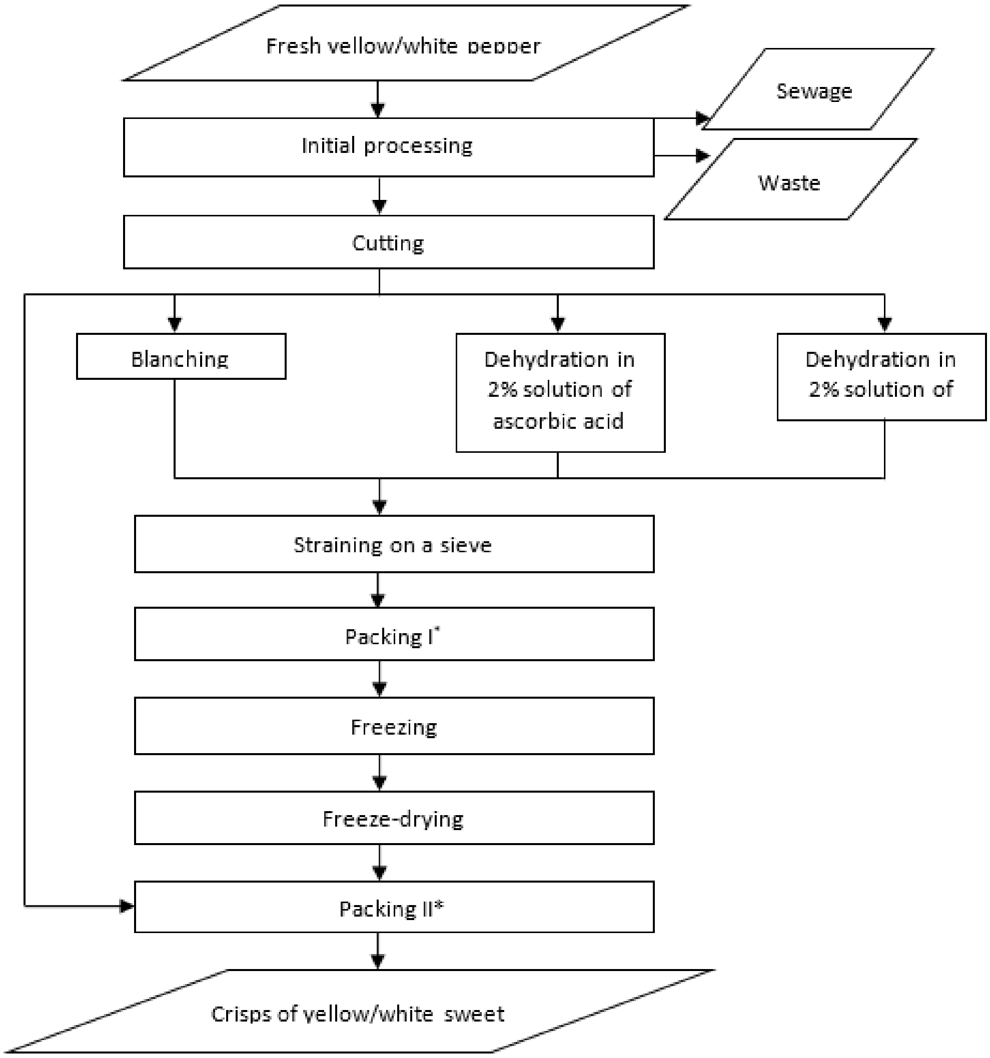
Material and methods

The research material consisted of two cultivars of sweet yellow and white pepper Shanghai F1 and Belladonna F1 from Poland. Sweet pepper class 1 quality were purchased in September 2019 on the retail market.

Yellow pepper Shangahi F1 block type was characterised with a previous harvesting maturity, uniform colour and shape and shiny skin. Its fruit with a prism shape had a great mass from 200 to 250 g and dimensions 10x11 cm. Thickness of pepper was 8 to 9 mm.

Early cultivar white sweet pepper Belladonna F1 of a block type has a prism shape with 3 to 4 cells with dimensions of 9 x 10 cm, average mass from 160-200 g and wall thickness from 7 to 8 mm. Moreover, it had a uniform white and cream colour.

Raw materials had no disqualification properties related, *inter alia*, with mechanical damages, presence of pests, mould, scalding, loss of turgor and symptoms of decay.



* Packing I in HDPE Ziplock bags; ** Packing II in 0.9 l, glass jars closed with an aluminium twist – off cap.

Figure 1. Technological schematic representation of obtaining yellow and white sweet pepper crisps

Author's own study

Vegetables were washed, cores were manually removed, and they were crushed before microbiological analyses were performed. Dried quarters of sweet pepper were cut into thin 2-3 mm thick slices with a multifunctional kitchen robot Siemens type MK 55300 with 110 W power.

Raw materials before sublimation drying were subjected to initial processing according to 4 following combinations:
– no initial processing,
– blanching in water for 2 minutes in 98°C,
– dehydration (enrichment) in 2% ascorbic acid solution for 20 minutes in 70°C,
– dehydration in 2% sodium chloride solution for 20 minutes in 70°C.

The sublimation drying process was carried out with lowered pressure of 64Pa and the temperature exceeding -18°C in a freeze-drier CT - 60 type.

Figure 1 presents a schematic representation of the laboratory method of obtaining crisps from yellow and white sweet pepper.

In the investigated material, the dry substance content was determined with a weight drier BTS 110 D type by AXIS, vitamin C content with Tilmans method (PN-A-04019:1998) and concentration of reducing sugars with DNS reactor (3.5-dinitrosalicylic acid) (Derlacz et al., 2009). Statistical development of research results was carried out with analysis of variance of experiments (ANW) version 2.1. This program was created and developed in DOS system by Stanisław Mańko (the University of Technology and Life Sciences in Bydgoszcz). This analysis enables indication of factors which significantly differentiated physico-chemical properties of the obtained product and raw material. In case significant differences were reported, values of the smallest significant differences were presented in tables (NIR at $\alpha = 0.05$),

Research results

Physico-chemical assessment of raw material

Based on the obtained research results (table 1) yellow pepper Shanghai F1 cultivar was the richest in vitamin C. Its content in fresh mass of raw material was 132.50 mg/100 g of fresh mass. On the other hand, if white cultivar *Belladonna* F1 it was respectively 125 mg/100 g of fresh mass of the product. Analysis of variance proved that both cultivars were significantly different with regard to the ascorbic acid content.

The highest content of ascorbic acid included in dry mass of the product was reported in a cultivar of white pepper *Belladonna* F1 2136.75 mg/100 g ss. This value is by 510.98 mg higher in comparison to the yellow pepper cultivar.

The level of natural antioxidant compounds including vitamin C depends mainly on the cultivar, genetic factors, manner of cultivation, maturity level, and colour of pepper (Hallmann and Rembiałowska 2007a; Hallmann and Rembiałowska 2007b; Perucka and Materska 2004). Sweet pepper cultivars compared to hot pepper have a lower content of ascorbic acid. The yellow cultivar has the lowest amount of the acid among other pepper cultivars and it amounts to 135.8 mg/100 g of fresh mass. (Perucka and Materska, 2007). In the research on yellow pepper Cieślewicz and Grzelakowska (2011) proved that the amount of vitamin C in dry mass amounts to 1821mg/100g of dry substance. The obtained values for yellow pepper Shanghai F1 were similar and were respectively 132.50 mg/100 g of fresh mass and 132.50 mg/100 g of fresh mass. Zalewska-Korona et al., (2015) in their research showed that the amount of vitamin C in white pepper Belladonna cultivar was at the level of 147.60 mg/100 g of fresh mass and yellow pepper Shanghai 148.23 mg/100 g of fresh mass. The content of this compound per dry mass was respectively for white cultivar 2226.24 mg/100 g of dry substance and for yellow 2861.58 mg/100 g of dry substance (Zalewska-Korona et al., 2015). The values of the obtained results of own research for white and yellow pepper in fresh mass were lower. On the other hand, the range of the index for white pepper *Belladonna* F1 in dry mass were comparable.

Table 1.
Content of vitamin C, reducing sugars and dry substance in fresh pepper

Type of material	Vitamin C content	
	(mg/100 g of fresh mass of the product)	(mg/100 g of dry substance)
Fresh yellow sweet pepper *Shanghai* F1	132.50	1625.77
Fresh white sweet pepper *Belladonna* F1	125.00	2136.75
***NIR (I) $_{cultivar}$ =1.686		
Type of material	Content of reducing sugars	
	(g glucose/100g of fresh mass of product)	(g glucose/100 g of dry substance)
Fresh yellow pepper *Shanghai* F1	1.05	12.92
White fresh pepper *Belladonna* F1	8.32	142.15
**NIR (I) cultivar =2.004		
Type of material	Dr matter content (%)	
Fresh yellow pepper *Shanghai* F1	8.15	
White fresh pepper *Belladonna* F1	5.85	
NIR (I) $_{cultivar}$ = 1.100		

Sweet pepper of two cultivars was analysed also on account of the reducing sugars content (table 1). Fresh white pepper *Belladonna* F1 had the highest content of reducing sugars in fresh and dry mass. Respectively the value was 8.32 g of glucose in 100 g of fresh mass and 142.15 g of glucose per 100 g of dry mass.

In case of studies on the reducing sugars content, the analysis of variance also showed significant differences in comparison to a pepper cultivar.

Sweet pepper has simple sugars in its chemical composition, where saccharosis has the lowest participation of 0.1 g (Golcz et al., 2009; Kunachowicz et al., 2000). According to the studies carried out by Kosson et al., (2010) the cultivar and method of cultivation have a significant impact on the reducing sugars content in fresh pepper (Kosson et al., 2010). Their growth may be caused by physiological maturation that takes place in time (Golcz, 1999).

The average content of reducing sugars which was obtained in the studies on fresh pepper Ożarowska and Roberta organically cultivated was 4.06 g of glucose /100 g fresh mass and in case of traditionally cultivated 3.38 g glucose /100 g fresh mass (Rembiałowska and Hallmann, 2008). The use of fertilizers during cultivation of pepper raises considerably the content of reducing sugars that are present in raw material, shortens the maturation time and dyeing of fruit (Golcz et al., 2009; Szwejda-Grzybowska, 2011). The amount of reducing sugars present in white pepper Belladonna F1 considerably exceeded previously listed norms.

Analysis of the research results proved that the highest % of dry mass content was reported in yellow pepper Shanghai F1 and was 8.15 %. However, in white pepper Belladonna F1, the level of dry mass was by more than 2% lower. The relevant content of dry mass in raw material determines its quality, usefulness for processing and resistance to transport damage. Cultivators aim at obtaining a culitvar with the highest increase of dry mass (Golcz et al., 2009). A significant impact on the value of this index of quality has the stage of maturity, soil and climatic conditions, cultivar, and the manner of fertilization (Zalewska-Korona et al., 2015; Golcz et al., 2009). The content of dry mass in pepper cultivated with organic or traditional method should be within 8.45-9.58 % (Hallmann et al., 2007). With this regard, sweet pepper cultivars subjected to the experiment were below this norm. It could have resulted from a longer storage of sweet pepper fruit before their purchase (Favell, 1998). Zalewska-Korona et al., (2015) in the experiment proved that the content of dry substance in white pepper Belladonna F1 is 6.63% and in the yellow cultivar Shanghai F1 5.18% (Zalewska-Korona et al., 2015). These values were lower than the ones obtained in these studies.

Physico-chemical assessment of the product

Dehydration in 2% solution of salt materially influenced the average dry matter content in yellow pepper crisps -93.41% (table 2). Its increase in comparison to the fresh raw material took place by 83.7%. The lowest % participation of dry mass was reported with reference to lyophilizates made of fresh yellow pepper 91.20% (it was 83.05% higher than the control sample).

Table 2.
Dry mass content in pepper crisps (%)

Type of material	Storage time		
	30	60	Average
Fresh yellow pepper crisps	92.00	90.40	91.20
Blanched yellow pepper crisps	95.40	90.60	93.00
Yellow pepper crisps + vit C	95.10	93.10	94.10
Yellow pepper crisps + NaCl	96.00	94.70	95.35
Average	94.62	92.20	93.41
Fresh white pepper crisps	92.20	91.90	92.05
Blanched white pepper crisps	95.00	92.20	93.60
White pepper crisps +vit C	93.60	92.50	93.05
White pepper crisps +NaCl	94.40	92.10	93.25
Average	93.80	92.17	92.89
**NIR (I) cultivar = 0.225		**NIR (II) processing type= 0.319	
**NIR (III) storage time = 0.225			

Similarly, as in case of yellow pepper crisps dehydration in the kitchen salt solution also influenced the increase of the average growth of the dry mass content in white pepper lyophilizates (92.82%). This content was higher by 86.97% in comparison to the basic raw material. The highest average decrease of this index was reported in crisps made of fresh white pepper and it was 92.05%. With this regard, it exceeded fresh yellow pepper by 86.2%.

Osmotic dehydration in ascorbic acid solutions and sodium chloride solutions influenced the stability of increase of dry mass in time. Dehydration in the sodium chloride solution also caused the increase of dry substance investigated above mentioned by Figiel et al., (2011) freeze-dried pumpkin and beets by Lech et al., (2011).

Lyophilizates of sweet pepper in powder investigated by Sharma et al., (2015) had a dry substance content of 90.38-90.58%. With this regard, the dried pepper dehydrated in 0.6% ascorbic acid solution exceeded dried vegetables without processing (90.38% of dry substance) and the blanched one (90.48% of dry substance) (Sharma et al., 2015).

The vitamin C content in 100 g of dry substance of lyophilizates of two types of pepper cultivars (table 3) was reduced in comparison to the control sample and storage time. Yellow pepper crisps dehydrated in the ascorbic acid solution were the richest in vitamin C. Its average value when stored was in the amount of 206.52 mg/100 g of dry substance and was by 87.4% lower than the content of vitamin C of the control sample. Crisps made of blanched yellow pepper had the lowest content of ascorbic acid, which was 94.41 mg/100 g of dry substance. Reduction of its value in comparison to the output raw material was 94.19%.

Freeze-dried blanched white pepper had the highest average content of vitamin C (93.93 mg/100g of dry substance) during storage. Its reduction in comparison to the control sample was 95.6%. The highest losses of vitamin C compared to other freeze-dried products and output raw material was reported in crisps with addition of NaCl (63.45 mg/100g of dry substance). The vitamin C content in dry mass of fresh white pepper was by 97.04% higher. The pepper cultivar was a factor that significantly differentiated the ascorbic acid content in crisps (NIR $_{\alpha=0.05}$ = 0.342).

Table 3.
Vitamin C content in pepper crisps in the storage time (mg/100 g dry substance).

Type of material	Storage time		
	30	60	Average
Fresh yellow pepper crisps	251.76	45.18	148.47
Blanched yellow pepper crisps	96.86	91.95	94.41
Yellow pepper crisps + vit C	205.37	207.67	206.52
Yellow pepper crisps + NaCl	148.96	55.37	102.17
Average	175.74	100.04	137.89
Fresh white pepper crisps	87.72	50.28	69.00
Blanched white pepper crisps	114.41	73.44	93.93
White pepper crisps +vit C	102.58	48.78	75.68
White pepper crisps +NaCl	67.90	59.00	63.45
Average	93.15	57.88	75.51
**NIR (I) cultivar = 0.342		***NIR (II) sample type= 0.484	
**NIR (III) $_{\text{storage time}}$ = 0.342			

Thus, it may be concluded that osmotic dehydration of yellow sweet pepper in ascorbic acid solution had a significant impact on maintaining stability of vitamin C during a 2-month storage. Sharma et al., (2015) obtained a similar result in their studies on dried red pepper in powder. They stated that dehydration of fresh pepper in 0.25 -0.6% solution of ascorbic acid before drying influenced maintaining its stability in a dried product (Sharma et al., 2015).

A higher content of vitamin C in freeze-dried fresh pepper without processing in the first month of storage was caused by no washing in water and water solutions (Sharma et al., 2015; Vega-Galvez et al., 2008; Wiriya et al., 2009). Reduction of the ascorbic acid content in the dried sample of sweet pepper subjected to blanching could have been a reason for its leaching during the initial processing. Sharma et al., (2015) had the same conclusions in their studies on the blanched dried pepper and Sikora et al., (2008) when investigating dry vegetables subjected to previous blanching. Vitamin C is quite sensitive to high temperatures, oxidating factors and water solubility (Davey et al., 2000). The lower is the moisture content in dried products the losses are smaller (Rudy, 2001). Dried products obtained from blanched white pepper in the authors' own research had the lowest content of vitamin C in comparison to lyophilizates of other combinations. Rahman et al., (2015) during their studies on lyophilizates made of green pepper stored in 20°C proved that the content of vitamin C had a decreasing trend (Rahman et al., 2015). Susceptibility of freeze-dried products to oxidation of vitamins could also have been related to their porosity. The size of pores depends on the speed and size of freezing of crystals of water stage. Improper and slowly performed process of initial freeze-drying may cause permanent damage to the cell structure of raw material (Ciurzyńska et al., 2013; Gruda and Postolski, 1999; Sun, 2008).

The decrease of Vitamin C content in dried products could have depended also on the conditions in which they were stored within 2 months. It could have resulted from untightness of package and an increased temperature ad moisture (Nowacka et al., 2011).

Addition of the ascorbic acid significantly influenced the increase of the reducing sugars in yellow pepper crisps in comparison to other lyophilizates. These sugars were at the level of 223.4 g of glucose/100 g of dry substance and exceeded the input raw material by 94.63%. The reduction of the content was visible on the example of blanched yellow crisps where they were 149.16 g of glucose /100 g dry substance. (by 91.96% more than in raw material). White pepper crisps dehydrated in the kitchen salt solution had the highest average sugar content - 179.87 g of glucose/100 g of dry substance. (By 26.53% higher than the control sample). However, the poorest source of reducing saccharides were blanched white pepper crisps on average 116.28 g of glucose / 100 g dry substance. The content of sugars was lower by 18.2% in comparison to the basic raw material.

The level of reducing sugars content in yellow pepper crisps that were osmotically dehydrated in the solution of ascorbic acid exceeded other lyophilizates during storage. A similar relation during storage of sweet pepper dehydrated in the 0.6 % water solution of ascorbic acid was reported by Sharma et al., (2015). This value was higher in comparison to the lyophilizate without initial processing and with previous blanching (Sharma et al., 2015). The amount of reducing sugars in freeze-dried products during a storage period was reduced. After the second month of storage the highest amount of reducing sugars was in case of lyophilizates made of fresh white pepper - 123.82 g of glucose /100 g of dry substance. However, products obtained from blanched white pepper had the lowest richness in this index which was 63.25 g of glucose /100 g of dry substance.

Table 4.
Reducing sugars content in pepper crisps in the storage time (g glucose 100 g of dry substance).

Type of material	Storage time		
	30	60	Average
Fresh yellow pepper crisps	269.22	121.10	195.16
Blanched yellow pepper crisps	265.92	32.41	149.16
Yellow pepper crisps + vit C	274.61	172.20	223.40
Yellow pepper crisps + NaCl	238.27	165.51	201.89
Average	262.00	122.80	192.40
Fresh white pepper crisps	203.22	123.82	163.52
Blanched white pepper crisps	169.31	63.25	116.28
White pepper crisps +vit C	214.12	91.83	152.97
White pepper crisps +NaCl	239.74	120.01	179.87
Average	206.60	99.73	153.16
**NIR (I) cultivar = 0.327		**NIR (II) processing type= 0.463	
*NIR (III) $_{\text{storage time}}$ = 0.372			

Conclusions

1. Analysis of variance proved that the physico-chemical quality of the obtained lyophilizates from sweet pepper was caused by a cultivar, type of processing and storage time. These factors significantly differentiated the content of vitamin C, reducing sugars and dry substance in sweet pepper crisps.
2. Initial hydration in the ascorbic acid solution led to the highest growth of vitamin C in dry mass of lyophilizates from yellow pepper. However, blanching affected the increase of the average content of vitamin C in dry mass of crisps made of white pepper.
3. A considerable increase of the reducing sugars in lyophilizates was caused with the previous dehydration of raw material. Water osmosis in the ascorbic acid solution caused reducing sugars in dry mass of crisps of yellow pepper. On the other hand, the content of reducing sugars present in dry mass of crisps from white pepper was caused by initial dehydration of raw material in the sodium chloride solution.
4. Under the influence of the initial freezing in the solution of salt the increase of concentration of dry substance in crisps made of both pepper cultivars took place. Sublimation freeze-drying pepper made of the initial processing had the highest dry substance.

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OBRÓBKA WSTĘPNA, SUSZENIE SUBLIMACYJNE I CZASU PRZECHOWYWANIA CRIPSÓW Z PAPRYKI. JAKOŚĆ FIZYKOCHEMICZNA – CZĘŚĆ I

Streszczenie. W pracy przedstawiono wpływ odmiany papryki, obróbki wstępnej i czasu przechowywania na jakość fizykochemiczną liofilizowanych cripsów. Paprykę po wstępnym umyciu i rozdrobnieniu poddano 4 kombinacjom obróbki wstępnej. Pierwsza z kombinacji obejmowała zamrażanie, druga blanszowanie w temperaturze 98°C i czasie 2 minut, trzecia odwadnianie w roztworze 2% kwasu askorbinowego oraz czwarta odwadnianie w 2% roztworze chlorku sodu. Obydwa rodzaje odwadniania prowadzono w temperaturze 70°C przez 20 minut przy stosunku surowca do roztworu osmotycznego wynoszącego 1:4. Blanszowane i odwodnione surowce poddano zamrażaniu w temperaturze -18°C przez 24 h. Po zakończonym procesie zamrażania próbki przeniesiono do liofilizatora i suszono sublimacyjnie przy temperaturze -18°C i obniżonym ciśnieniu równym 63 Pa. Na podstawie przeprowadzonych analiz badawczych stwierdzono istotne zróżnicowanie cech fizykochemicznych otrzymanych liofilizatów papryki względem odmiany, rodzaju obróbki i czasu przechowywania. Najbardziej zbliżoną jakościowo do surowca świeżego odznaczały się liofilizaty papryki żółtej odwodnione w roztworze kwasu askorbinowego. Czas przechowywania znacząco wpływał na obniżenie cech jakościowych cripsów z papryki.

Słowa kluczowe: papryka, liofilizacja, jakość, obróbka, cripsy