EFFECT OF FRUIT AND VEGETABLE BLANCHING AND COMPRESSION ON THE LOSS OF MULTILAYER CHIPS
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ВПЛИВ БЛАНШУВАННЯ ТА СПРЕСОВУВАННЯ ФРУКТІВ І ОВОЧІВ НА ВТРАТИ БАГАТОШАРОВИХ ЧИПСІВ

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DOI: https://doi.org/10.356.33/inmateh-64-24

Keywords: *fruit chips, vegetable chips, blanching time, chips loss, chips technology*

ABSTRACT
Chips are a useful and popular product that is produced in most countries of the world. The main processes of traditional chips technology are slicing fruits and vegetables into thin slices, blanching and drying slices. Multilayer chips are formed from several layers of different materials (fruits, vegetables and seeds). For forming of such chips, it is important that the layers of different materials stick together well. Studies have shown that the material type and blanching time significantly affect the adhesion of material and loss of chips. Also, effect of compression of raw material layers on the chips loss was studied.

АНОТАЦІЯ
Фруктові та овочеві чипси – це корисний і популярний продукт, який виробляється в більшості країн світу. Основними процесами традиційної технології виробництва чипсів є нарізування фруктів та овочів на тонкі скибочки, бланшування та сушіння скибочок. Багатошарові чипси формуються із декількох шарів різної сировини, такої як фрукти, овочі та насіння. Для формування таких чипсів важливо, щоб шари різної сировини добре злипалися. Експериментальні дослідження продемонстрували, що вид сировини та час її бланшування суттєво впливають на липкість сировини та втрати чипсів. Також досліджувався вплив спресовування шарів сировини на втрати чипсів.

INTRODUCTION
Chips are very popular type of snack food in most countries of the world. A broad variety of chips made by different technologies are available in the market. An assortment of chips includes potato chips, corn chips, tortilla chips, fruit chips, vegetable chips etc. Chips may be classified according to raw materials used in their production (fruits, vegetables, corns etc.) and specific unit operations (baking, drying, extrusion, frying etc.) for their manufacture *(Pedreschi et al., 2018)*. New types of chips and technologies for their manufacture are constantly being developed by scientists and snack food producers. In particular, the apple chips technology using osmotic pre-treatment in cherry or apple concentrated juices before convection drying was developed, which enriches chips with additional natural nutrients and improves their color and taste *(Kowalska et al., 2018)*.

Fruit and vegetable chips are the most useful types of snack food for the human body. The manufacturing technology of such chips, as well as potato chips *(Pedreschi et al., 2007)*, includes the processes of washing, peeling, sorting, cutting into slices and blanching of raw materials. But in contrast to the potato chips manufacturing technology, where potato slices are fried, in the production of fruit and vegetable chips, technology involves the drying process of fruit and vegetable slices.

It is known that drying is one of the most common techniques used to preserve food *(Prawiranto et al., 2019)*. Drying of fruits and vegetables is a complicated process *(Diamante et al., 2010)* and involves simultaneous mass and heat transfer accompanied by physical and structural changes *(Senadeera et al., 2000)*. Also, drying process reduces water activity of fruits and vegetables products, which inhibits microbial growth and decreases degradative reactions, resulting in higher stability *(Abano et al., 2019)*. Dehydration, which occurs during fruits and vegetables drying in thin-layer, leads to a change in textural characteristic of finished products *(Ramos et al., 2003)*. For consumers, the texture is one of the most significant quality characteristic of chips since the texture makes a dominant contribution to the overall quality and acceptability

(Kayacier and Singh, 2003). Therefore, it is very important that the changes, which occur during fruits and vegetables drying, do not lead to a significant deterioration in the quality properties of chips compared to the quality properties of fresh fruits and vegetables.

In the food industry, different drying methods are applied, including solar drying, convective drying, microwave drying, osmotic dehydration, freeze drying, spray drying, superheated steam drying, and vacuum drying *(Sagar and Suresh Kumar, 2010)*. An optimal drying method should be cost effective, and must have a shorter drying time with minimum damage to the product. For dehydration of fruits and vegetables, some new drying technologies were developed, such as infrared radiation drying, microwave drying, radio frequency drying, electrohydrodynamic drying, dielectric drying, and hybrid drying methods combining two or more different drying techniques *(Zhang et al., 2017)*. Due to the unique characteristics of fruits and vegetables, there are different choices for the dehydration process and each one has certain characteristics that affect the drying behavior and the final foodstuff quality *(Santos and Silva, 2008)*. The various conditions affecting the drying of sliced fruits and vegetables include air velocity, drying temperature, size and shape of slices, slice thickness and the relative humidity *(Onwude et al., 2016)*.

Blanching is an important technological operation for preparing fruits and vegetables for drying, because blanching has resulted in increasing the drying rate of products *(Dandamrongrak, 2003)*. In particular, it is determined that steam treatment shortens the drying process by 20 – 30% than the raw fruit dehydration *(Husarova and Shapar, 2017)*. The main purpose of blanching is to inactivate enzymes responsible for deterioration of fresh fruits and vegetables such as peroxidase and polyphenol oxidases *(Aktas et al., 2007)*. Thermal processing of fruits and vegetables has pronounced effects on the cell structure, often negatively affecting the final textural properties of the product *(Neri et al., 2011)*. Also, temperature and blanching time significantly reduced in bioactive components, and firmness of fruits and vegetables *(Eyarkai Nambi et al., 2016)*. The color of fruits and vegetables changes considerably during blanching *(Tijskens et al., 2001)*. Quality characteristics of fruits and vegetables after blanching depend on the method of blanching and the initial properties of fresh raw materials.

The various types of blanching methods include water blanching, steam blanching, vacuum steam blanching, in-can blanching, microwave blanching and hot-gas blanching *(Selman, 1994)*. Blanching parameters, such as temperature and blanching time, depend on the quality characteristics of raw materials and subsequent technological processes of chips manufacturing. For example, blanching at a high temperature and short time is recommended for vegetable soybeans *(Song et al., 2003)* and the best blanching parameters for carrots are temperature of hot water about 95ºC and blanching time about 5 min *(Shivhare et al., 2009)*. Typically, the blanching process utilizes temperatures around 75 – 95ºC *(Selman, 1994)* for times of about 1 – 10 min *(Xiao et al., 2017)*, depending on the product requirements.

The influence of different methods of blanching on the finished product quality has been studied by scientists. Thus, vegetables blanched with microwave energy are more nutritious than those heated to the same temperature by conventional water blanching *(Ramesh et al., 2002)*. Also, a vitamin C decrease is not observed in microwaved broccoli *(Severini et al., 2016)*. The thermosonication is a potential alternative to conventional thermal treatments, the impact of which on food quality attributes is lower than the ones observed with heat blanching *(Alexandre et al., 2011)*.

When forming foods, such as multilayer chips from different layers of raw materials, it is important that the layers stick together well. There are many food-related and non-food related factors and forces, which affect the stickiness (adhesion) of food materials, such as moisture content, temperature, viscosity and type of the food, compression of a food system, and a combined effect of adhesive and cohesive forces *(Adhikari et al., 2001)*. Researches have proposed various methods to determine a food material adhesion, but the simplest method is to weigh the material remaining on the contact surface *(Michalski et al., 1997)*.

The aim of the study is to determine the effect of fruit and vegetable blanching and compression of raw material layers on the loss of multilayer chips.

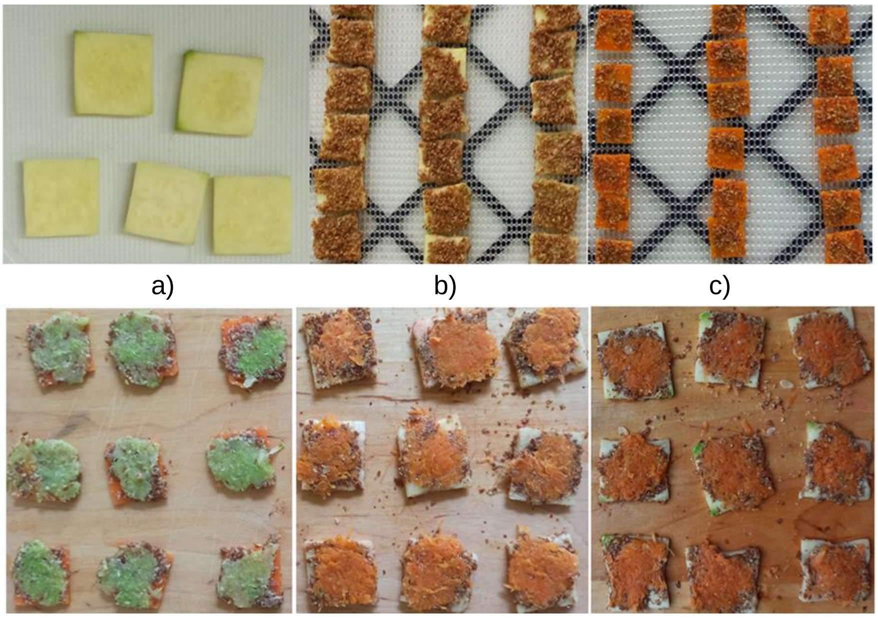
MATERIALS AND METHODS

Sample preparation

Multilayer chips can be made from different combinations of fruits, vegetables and seeds. Loss of multilayer chips during technological processes depends on the fruits and vegetables properties and processing regimes of chips production. Multilayer chips were formed from two or three layers of fruits, vegetables and seeds. The first layer (the main layer) of all types of chips was formed from a rectangular-shaped slice of fruit or vegetable. For the main layer, slices of fruit and vegetables were blanched.

The first layer is the basis of multilayer chips, because all other layers were formed on it. The second layer of all types of chips was formed by breading of one slice side with crushed seeds. As a raw material for the second layer of chips, flax seeds were used, which contain a large amount of nutrients and lignin, which ensures the bonding of the layers of chips. The third layer of three-layer chips was formed from grated fruits or vegetables. Grated vegetables were blanched and grated fruits were not blanched.

Local raw fruits, vegetables and seeds such as zucchini, carrots, apples and flax seeds were used to form the multilayer chips. Flax seeds, fresh fruit and vegetables purchased from local markets were randomly sampled. Fruits and vegetables were cleaned, peeled and sliced into rectangular-shaped slices with dimensions $a \times a$ and thickness h (fig. 1, a). The slice surface did not contain peel. The slice thickness h was as follows: for zucchini slices – 3 mm, 5 mm and 7 mm; for carrot slices – 1 mm, 2 mm and 3 mm; for apple slices – 2 mm, 3 mm and 5 mm. The slice dimensions $a \times a$ were as follows: for zucchini slices – 3 cm $\times$ 3 cm; for carrot and apple slices – 2 cm $\times$ 2 cm. The area s of the slice surface, which was breaded with crushed seeds, was as follows: for zucchini slices – 9 cm^2; for carrot slices – 4 cm^2; for apple slices – 4 cm^2.



a) b) c) d) e) f)

Fig. 1 - Rectangular-shaped zucchini slices (a), and formed samples of some types of two-layer chips, such as ZF (b) and CF (c), and three-layer chips, such as CFZ (d), AFC (e) and ZFC (f)

For the second layer of chips flax seeds were crushed. The percentage of seed particles, which was determined by the sieve method on sieves with round orifices, was for seed particle size: more than 3 mm – 1.9%; from 2 mm to 3 mm – 54.8%; from 1.1 mm to 2 mm – 40%; from 0.5 mm to 1.1 mm – 3.1%; from 0.25 mm to 0.5 mm – 0.2%.

For the third layer of chips, fruits and vegetables were grated. The sizes of the grated raw materials were as follows: the length – less than 10 mm; the width – less than 5 mm; thickness – less than 1 mm.

Three variants of two-layer chips were studied (fig. 1, b, c):

- the first layer of chips was formed by a zucchini slice, and the second layer was formed by crushed flax seeds (the designation of the variant is ZF);
- the first layer of chips was formed by a carrot slice, and the second layer was formed by crushed flax seeds (the designation of the variant is CF);
- the first layer of chips was formed by an apple slice, and the second layer of was formed by crushed flax seeds (the designation of the variant is AF).

Nine variants of three-layer chips were also studied:

- the first layer of chips was formed by a carrot slice, and the second layer was formed by crushed flax seeds, and the third layer was formed by grated carrot (the designation of the variant is CFC);
- the first layer of chips was formed by a carrot slice, and the second layer was formed by crushed flax seeds, and the third layer was formed by grated zucchini (the designation of the variant is CFZ (fig. 1, d));
- the first layer of chips was formed by a carrot slice, and the second layer was formed by crushed flax seeds, and the third layer was formed by grated apple (the designation of the variant is CFA);

- the first layer of chips was formed by an apple slice, and the second layer was formed by crushed flax seeds, and the third layer was formed by grated apple (the designation of the variant is AFA);
- the first layer of chips was formed by an apple slice, and the second layer was formed by crushed flax seeds, and the third layer was formed by grated zucchini (the designation of the variant is AFZ);
- the first layer of chips was formed by an apple slice, and the second layer was formed by crushed flax seeds, and the third layer was formed by grated carrot (the designation of the variant is AFC (fig. 1, e));
- the first layer of chips was formed by a zucchini slice, and the second layer was formed by crushed flax seeds, and the third layer was formed by grated zucchini (the designation of the variant is ZFZ);
- the first layer of chips was formed by a zucchini slice, and the second layer was formed by crushed flax seeds, and the third layer was formed by grated apple (the designation of the variant is ZFA);
- the first layer of chips was formed by a zucchini slice, and the second layer was formed by crushed flax seeds, and the third layer was formed by grated carrot (the designation of the variant is ZFC (fig. 1, f)).

Instruments

During study, the main laboratory equipment was used, such as: slicer GORENJE R 506 E; dehydrator Excalibur 4926T Black; grinder Hamilton Beach Fresh Grind 4.5 oz; laboratory drying cabinet CNOL-3,5.3,5.3,5/3,5; thermometer Testo 405V1; laboratory balances FEN-V2003.

Moisture content determination

Moisture content of fruits and vegetables and multilayer chips was determined by standard method *(AOAC Official Method)*. Moisture content of fruits and vegetables was as follows: for zucchini – 94.9%; for carrots – 91.2%; for apples – 93.7%; for flax seeds – 6.4%. Moisture content of multilayer chips of all variants was between 6.3% and 8.5%.

Blanching of fruit and vegetable slices

Blanching of fruit and vegetable slices and grated vegetables was carried out by steam at a temperature of 85 – 95ºC. Blanching time t was as follows:

- for zucchini slices: 1 min, 2 min, 3 min and 5 min (h = 3 mm); 2 min, 3 min, 5 min, 7 min (h = 5 mm); 3min, 5 min, 7 min and 9 min (h = 7 mm);
- for carrot slices – 3 min, 5 min, 7 min and 9 min (h = 1 mm, h = 2 mm, h = 3 mm);
- for apple slices – 1 min, 2 min, 3 min and 5 min (h = 2 mm, h = 3 mm, h = 5 mm).

The time t of grated vegetable blanching was as follows: for grated zucchini – 2 min; for grated carrot – 3 min. Grated apples were not blanched.

Adhesion index determination

During the study, it was necessary to determine the adhesion index of fruits and vegetables and the ability of the chips layers to be joined and not crumble into crumbs after drying. Therefore, the effect of blanching time on the adhesion of the crushed seeds to chips first layer was determined. After blanching, the sample of sliced fruits or vegetables was weighed and breaded on one side with crushed seeds. After breading, the sample was weighed again. In the control variant (without blanching), the sample was weighed twice before and after breading. The adhesion index of sliced fruits and vegetables was calculated by the equation:

$$\lambda = (m_2 - m_1) / s, \quad (1)$$

where: λ is an adhesion index of sliced fruits and vegetables, g·cm^{-2}; m_1 is a mass of the sample of sliced fruits or vegetables before breading, g; m_2 is a mass of the sample of sliced fruits or vegetables after breading, g; s is the breaded surface area of the sample, cm^2.

Compression of chips layers

After forming samples of multilayer chips, the samples were compressed with a load of a certain mass m. Since the area s of the sample of multilayer chips (the size $a \times a$ of the first layer) and the force F of compression were known, the pressure on the sample was calculated by the equation:

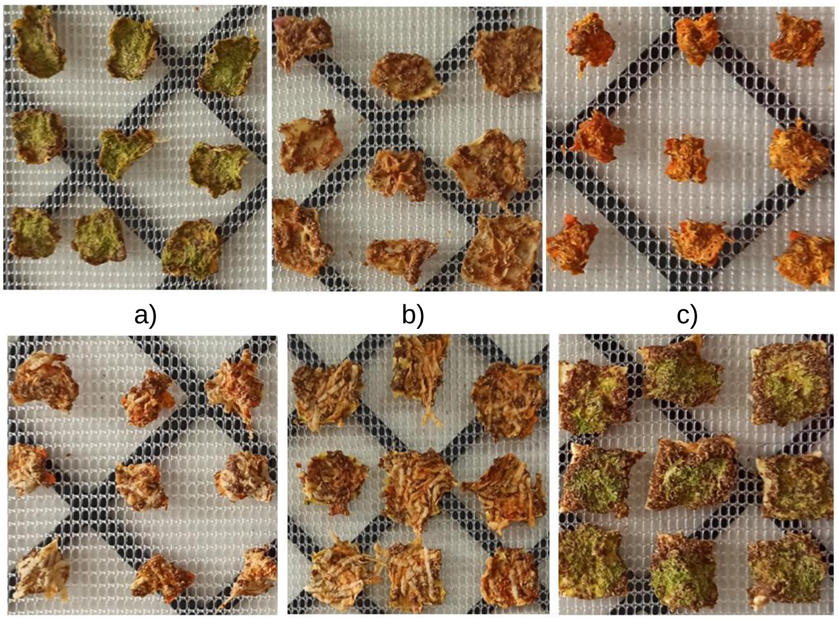
$$P = mg / s = F / s, \quad (2)$$

where: P is a pressure on the sample of multilayer chips, Pa; m is a mass of load, kg; g is an acceleration of gravity, m·s^{-2}; F is a force of compression, N; s is a surface area of the sample of multilayer chips, m^2.

During the study, the pressure P on the sample of chips was as follows: 4.0 kPa, 4.9 kPa and 5.5 kPa.

Drying of multilayer chips samples

The convective method of drying was used for multilayer chips samples drying. For all types of multilayer chips, the drying temperature was about 63ºC. For two-layer chips (fig. 2, a, b, c), the drying time was as follows: for chips with the first layer made of zucchini – 5.5 h; for chips with the first layer made of apple – 4.0 h; for chips with the first layer made of carrot – 3.0 h. For all variants of three-layer chips (fig. 2, d, e, f), the drying time was about 6.5 h.



a) b) c)

d) e) f)

Fig. 2 - Dried two-layer chips, such as ZF (a), AF (b) and CF (c), and dried three-layer chips, such as CFA (d), ZFA (e) and AFZ (f)

Determination of multilayer chips loss

Multilayer chips loss was determined after drying and cooling of the samples. For this purpose, samples of chips were placed in the parallelepiped-shaped container with dimensions 30 cm × 30 cm × 5 cm. The container rotated about 100 times and shook intensely, as a result of which the chips moved on its inner surfaces. In this way, the movement of chips on the working surfaces of the technological equipment was simulated. During the container rotating and shaking, crumbs of chips were formed. These crumbs are the losses of multilayer chips. After container rotating and shaking, multilayer chips and crumbs were weighed separately. Multilayer chips loss was calculated by the equation:

$$\eta = m_4 \cdot 100 / (m_3 + m_4), \quad (3)$$

where:

η is a chips loss, %; m_3 is a mass of multilayer chips after container rotating and shaking, g; m_4 is a mass of chips crumbs after container rotating and shaking, g.

Statistical analysis

The experimental data were processed using the methods of mathematical statistics *(Steel et al., 1997)* and computer software Mathcad 14. The coefficient of determination r^2 was also calculated.

RESULTS

Fig. 3, a presents the effect of zucchini slice blanching time t on the adhesion of crushed flax seeds to zucchini slices. Regardless of the zucchini slice thickness h, the adhesion index λ of blanched zucchini slices was greater than the adhesion index of non-blanched zucchini slices (the control variant). The results of the study show that the blanching time t significantly affects the adhesion index λ. With the time of the zucchini slice blanching up to 2 min, the adhesion index of the zucchini slices increased to 0.047 g·cm^{-2} (h = 3 mm) and to 0.054 g·cm^{-2} (h = 5 mm). For zucchini slices with a thickness of 7 mm the maximum adhesion index was 0.056 g·cm^{-2}. This value of the adhesion index was achieved with a blanching time of 5 min.

Regardless of the slice thickness, the increase in the blanching time more than 2 min (h = 3 mm, h = 5 mm) and more than 5 min (h = 7 mm) led to a decrease in the adhesion index of zucchini slices.

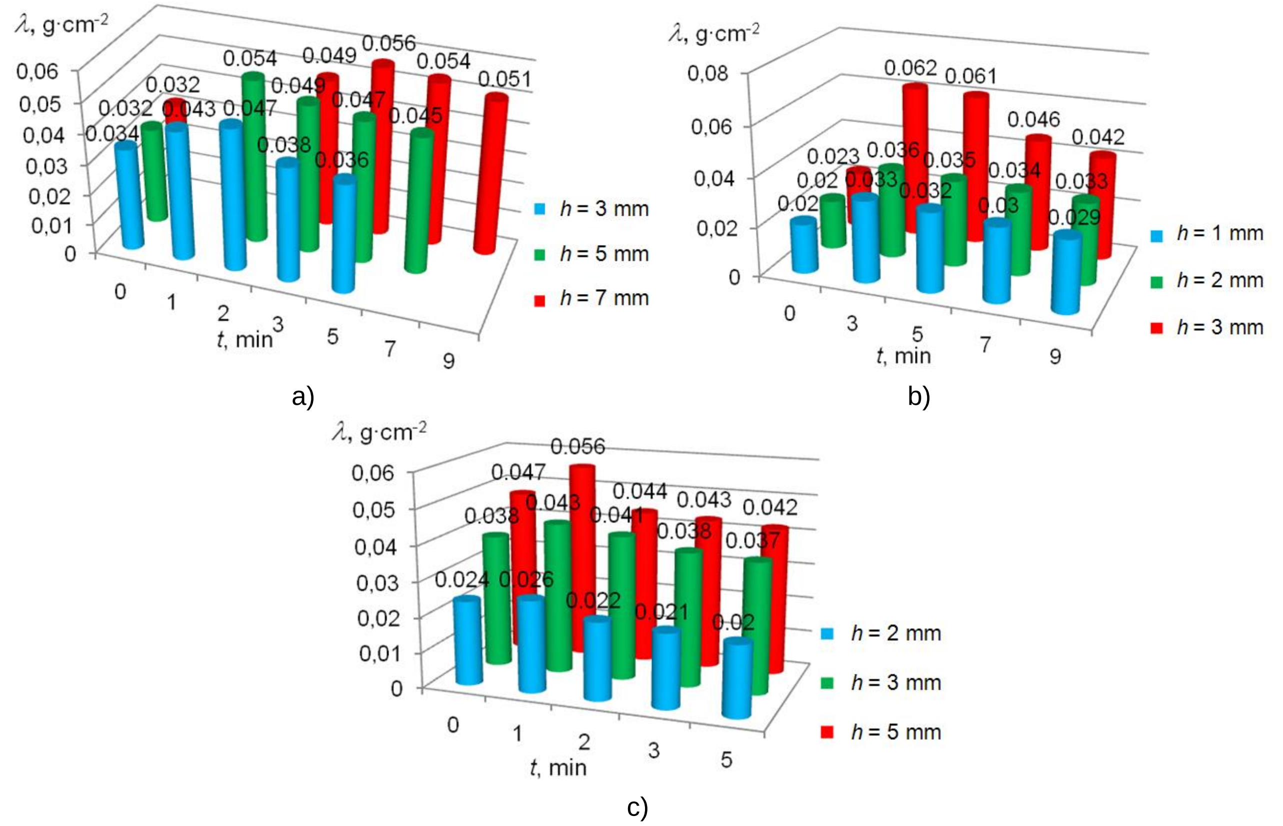


Fig. 3 - Effect of slice blanching time *t* on the adhesion index λ of slices with thickness *h*: zucchini slices (a); carrot slices (b); apple slices (c)

Fig. 3, b presents the effect of carrot slice blanching time *t* on the adhesion index λ of carrot slices. For all variants of the study, the adhesion index of blanched carrot slices was greater than the adhesion index of non-blanched carrot slices. In the case of carrot slice blanching of 3 min, the adhesion index was the highest: for slice thickness of 1 mm – λ = 0.033 g·cm^{-2}; for slice thickness of 2 mm – λ = 0.036 g·cm^{-2}; for slice thickness of 3 mm – λ = 0.062 g·cm^{-2}. Increasing blanching time more than 3 min led to a decrease in the adhesion index of carrot slices.

Fig. 3, c presents the effect of apple slice blanching time *t* on the adhesion index λ of apple slices. In the case of apple slice blanching about 1 min, the adhesion index was the highest: for the slice thickness of 2 mm – λ = 0.026 g·cm^{-2}; for the slice thickness of 3 mm – λ = 0.043 g·cm^{-2}; for the slice thickness of 5 mm – λ = 0.056 g·cm^{-2}. Increasing blanching time more than 1 min caused a decrease in the adhesion index to the level of the adhesion index of non-blanched apple slices.

Fig. 4, a shows the results of determination of chips (ZF) loss η. In case of zucchini slice thickness of 3 mm, the chips (ZF) had the smallest loss in the variant of blanching time of 2 min, which was about 9.3%. In the case of zucchini slice thickness of 5 mm, the smallest loss of chips was about 9.2% in the variant of blanching time of 3 min. And, in the case of zucchini slice thickness of 7 mm, the smallest loss of chips was about 9.5% in the variant of blanching time 5 min. Regardless of the zucchini slice thickness, the highest chips loss was observed in variants with non-blanched zucchini slices (h = 5 mm, h = 7 mm) and with blanching time of 5 min (h = 3 mm). Thus, in the variants with a high adhesion index of blanched zucchini, the loss of chips was the smallest.

Analysis of chips loss indicates that the highest loss η of two-layer chips (CF) was in variants with blanching time of carrot slices about 9 min (fig. 4, b). The smallest loss of chips (CF) was in variants in which blanched slices of carrot had the highest adhesion index λ. Thus, the smallest loss of two-layer chips (CF) was in variants with the blanching time about 3 min: for carrot slice thickness of 1 mm – η = 14.1%; for carrot slice thickness of 2 mm – η = 13.6%; for carrot slice thickness of 3 mm – η = 13.3%. It should be noted that the loss of chips (CF) decreased with increasing slice thickness. But, in the case of blanching time of 3 min, the loss of chips did not differ significantly for different variants of carrot slice thickness.

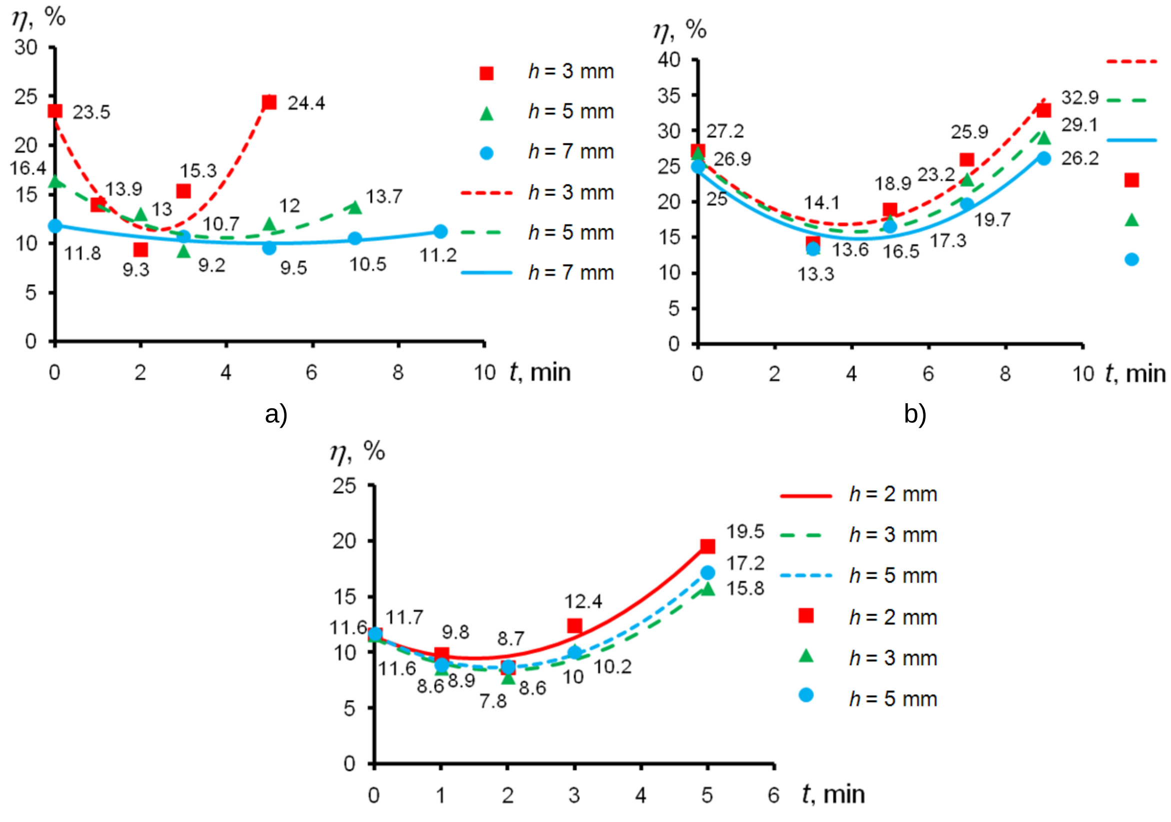


Fig. 4 - Effect of slice blanching time *t* on the loss η of two-layer chips with thickness of the main layer *h*: a) – chips (ZF); b) – chips (CF); c) – chips (AF)

In the fig. 4, c the results of determination of chips (AF) loss η is presented. In the variants with the longest time *t* of apple slice blanching, loss of two-layer chips (AF) was the highest. These are the same variants, which had the smallest adhesion index λ of blanched apple slices. The highest loss of two-layer chips (AF) was as follows: for apple slice thickness of 2 mm – η = 19.5%; for apple slice thickness of 3 mm – η = 15.8%; for apple slice thickness of 5 mm – η = 17.2%. Variants of chips with the high adhesion index λ of blanched apple slices had the smallest loss of chips (AF). So, in case of apple slice blanching time of 2 min, the loss of chips (AF) was the smallest: for apple slice thickness of 2 mm – η = 8.6%; for apple slice thickness of 3 mm – η = 7.8%; for apple slice thickness of 5 mm – η = 8.7%.

As a result of processing of experimental data, the equations describing effect of blanching time *t* (min) on the loss η (%) of two-layer chips were received:

- for chips (ZF) with thickness of the main layer *h* = 3 mm, *h* = 5 mm and *h* = 7 mm (fig. 4, a):

$$\eta = 1.974t^2 - 9.332t + 22.41,\ r^2 = 0.892, \quad (4)$$

$$\eta = 0.374t^2 - 2.968t + 16.44,\ r^2 = 0.814, \quad (5)$$

$$\eta = 0.076t^2 - 0.757t + 11.89,\ r^2 = 0.845, \quad (6)$$

- for chips (CF) with thickness of the main layer *h* = 1 mm, *h* = 2 mm and *h* = 3 mm (fig. 4, b):

$$\eta = 0.647t^2 - 4.911t + 26.15,\ r^2 = 0.907, \quad (7)$$

$$\eta = 0.608t^2 - 4.971t + 25.93,\ r^2 = 0.897, \quad (8)$$

$$\eta = 0.535t^2 - 4.525t + 24.32,\ r^2 = 0.927, \quad (9)$$

- for chips (AF) with thickness of the main layer *h* = 2 mm, *h* = 3 mm and *h* = 5 mm (fig. 4, c):

$$\eta = 0.839t^2 - 2.541t + 11.42,\ r^2 = 0.967, \quad (10)$$

$$\eta = 0.795t^2 - 3.027t + 11.26,\ r^2 = 0.964, \quad (11)$$

$$\eta = 0.859t^2 - 3.15t + 11.53,\ r^2 = 0.996. \quad (12)$$

The diagram (fig. 5, a) shows the effect of the pressure *P* of layer compression on the loss η of multilayer chips (ZFA, ZFC, ZFZ). Zucchini slices with thickness of 3 mm, which were blanched for 2 min, formed the first layer of multilayer chips (ZFA, ZFC, ZFZ). Analysis of the experimental data shows that the chips layers adhered better at higher pressure. Increase in pressure from 4.0 kPa to 5.5 kPa led to a decrease in multilayer chips loss: for chips (ZFZ) – from 13.2% to 7.8%; for chips (ZFC) – from 12.6% to 10.8%; for chips (ZFA) – from 8.7% to 7.3%.

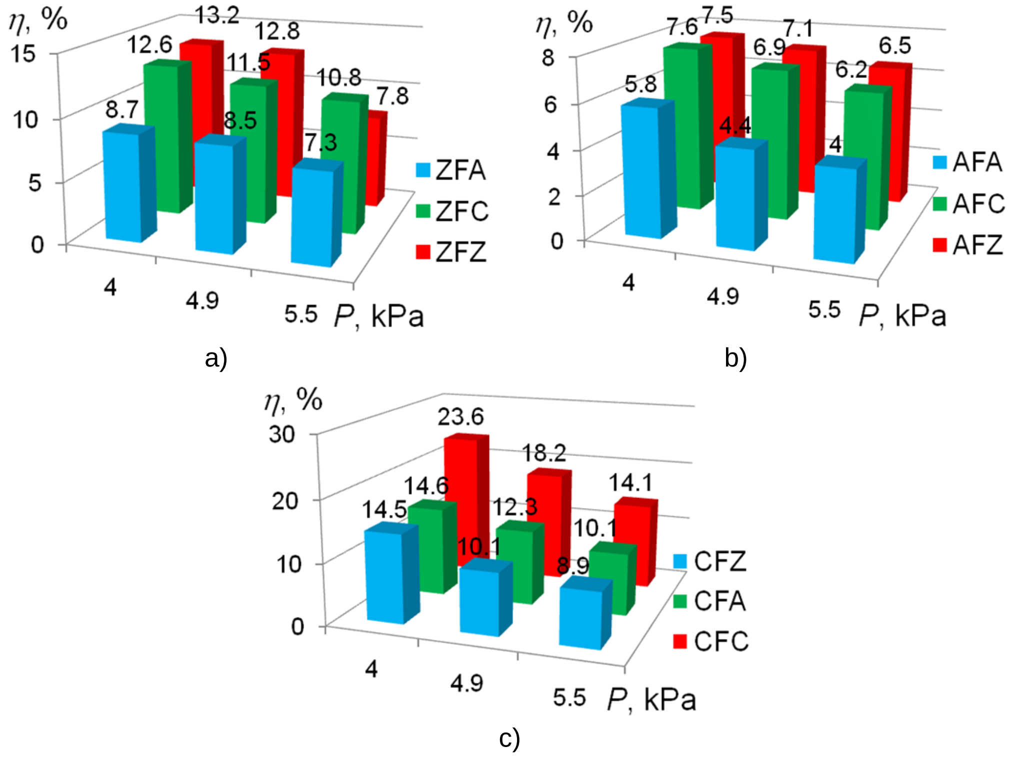


Fig. 5 - Effect of the pressure *P* of layer compression on the loss η of multilayer chips:
a) – ZFA, ZFC, ZFZ; b) – AFA, AFC, AFZ; c) – CFZ, CFA, CFC

The diagram (fig. 5, b) shows the effect of the pressure *P* of layer compression on the loss η of multilayer chips (AFA, AFC, AFZ). Apple slices with thickness of 3 mm, which were blanched for 2 min, formed the first layer of multilayer chips (AFA, AFC, AFZ). For multilayer chips (AFA, AFC, AFZ), increase in pressure from 4.0 kPa to 5.5 kPa led to a decrease in multilayer chips loss: for chips (AFA) – from 5.8% to 4.0%; for chips (AFZ) – from 7.5% to 6.5%; for chips (AFC) – from 7.6% to 6.2%.

The diagram (fig. 5, c) shows the effect of the pressure *P* of layer compression on the loss η of multilayer chips (CFZ, CFA, CFC). Carrot slices with thickness of 1 mm, which were blanched for 3 min, formed the first layer of multilayer chips (CFZ, CFA, CFC). Analysis of the experimental data shows that increase in pressure from 4.0 kPa to 5.5 kPa led to a decrease in multilayer chips loss: for chips (CFC) – from 23.6% to 14.1%; for chips (CFZ) – from 14.5% to 8.9%; for chips (CFA) – from 14.6% to 10.1%.

One of the goals of blanching of sliced fruits and vegetables, which formed the first layer of multilayer chips, is to ensure the high value of the adhesion index. In this case, the layers of chips will stick together. For the studied slices of zucchini, carrots and apples, the adhesion index increases with short-term blanching and decreases with long-term blanching. Also, it is important to remember that prolonged blanching causes the loss of nutrients and vitamins. So, the blanching should be as short a time as possible.

Analysis of the experimental data shows that apples and zucchini are the most suitable raw fruit and vegetable for the first layer of multilayer chips because the loss of such chips will be the smallest. In case of using zucchini and apples for first layer forming, the recommended thickness of zucchini and apple slices is about 3 mm and blanching time is about 2 min.

Experimental data show that increasing the pressure *P* from 4.0 kPa to 5.5 kPa reduced the loss η of multilayer chips because the layers of chips adhered better and less crumbs were formed after chips drying. Also, experimental data show that the chips, in which the first layer was formed by carrot slices, had the largest loss of chips.

CONCLUSIONS

During the production of multilayer chips, steam blanching of fruit and vegetable slices for 2 – 3 min at 85 – 95ºC causes an increase in adhesion index of sliced fruits and vegetables. Steam blanching of sliced fruits and vegetables in combination with the compression of the chips layers reduces the chips loss that is possible due to chips crushing and destruction during technological processes. Chips loss is a production waste that can be reused after grinding as a raw material for fruits and vegetables breading.

For the multilayer chips production, the recommended thickness of fruit and vegetable slices and blanching time depend on the type of fruits and vegetables: for first layer made of apples or zucchini, it is recommended to slice fruit and vegetable with the slice thickness of 3 mm and blanch slices for 2 min; for first layer made of carrots, it is recommended to slice carrots with the slice thickness of 1 mm and blanch carrot slices for 3 min. The second layer of multilayer chips can be formed by breading of one side of the main layer of chips with crushed flax seeds. The recommended seed particle size ranges from 1.1 mm to 2.0 mm. The third layer of multilayer chips can be formed of a thin layer of grated fruits or vegetables (zucchini, apples, carrots, etc.), which (vegetables) were blanched for about 2 – 3 min. For better adhesion of layers of multilayer chips, the recommended pressure of chips layers' compression is about 5.5 kPa. So, at the recommended parameters of processing of multilayer chips, the chips loss will be the smallest.

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