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Influence of Conective Drying on the Properties of Idared and Božićnica Apples, Cut Into Slices

NADICA DOBRIČEVIĆ

SUMMARY

This paper deals with the research that was carried out into the influence of convective drying on the properties of slices of Božičnica and Idared apples. The average sample of fruits weighing from 107.59 to 151.71 grammes produced 17.49 to 21.36% of epidermis, and 13.94 to 17.01% of seed cases, whereas the exploitability of fruits was 49.96 to 54.59%, with significant differences in Idared apples.

Prior to drying, the fruits were cut into 6 to 8 mm-thick slices which were then treated with an antioxidant and immersed into a 0.1% solution of L-ascorbic acid. Next, they were exposed to convective drying which was done in two stages and at different temperatures. During the first stage of drying, the air temperature varying from 80.37 to 83.90 ^{0}C heated the slices to 45.28 ^{0}C - 46.18 ^{0}C. The average drying air speed was 1.98 m/s, while the drying time was from 58 to 73 minutes for the 229.6 - 275.0 gramme samples. In the course of the second stage of drying, the air temperature from 65.25 to 70.90 ^{0}C heated the slices to 40.06 ^{0}C - 42.15^{0}C, with the air speed of 1.85 m/s and the drying time of 92 -114 minutes.

Fresh slices contain 12.36 - 15.60% of dry matter which increases after drying to 82.59 - 84.61%. The drying curves of the samples under research were modelled by the following equation of linear regression, showing no significant differences:

$$y = 88.0627 + (- 0.4281x * \text{min})$$

where determination coefficient

$$r = - 0.9812; \quad R^2 = 0.9628 \text{ and } s_x = 4.33.$$

The properties of fresh and dried slices were worked out by means of chemical analyses, organoleptic evaluations and rehydration ratios.

Testing of differences in dry matter content and saccharose among fresh and dried slices showed some statistically significant variations, whereas testing of differences in the amount of L - ascorbic acid, pH values and overall acidity among fresh and dried samples resulted in no statistically significant variations.

Rehydration ratio, one of the most important indicators of the quality of drying, varied from 4.03 to 4.90 and showed no significant differences.

Testing of differences in organoleptic colour values among dried slices showed some statistically significant variations in Božičnica apples.

KEY WORDS

convection, drying, Božičnica , Idared, slices

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NADICA DOBRIČEVIĆ

SAŽETAK

Istraživanje utjecaja sušenja na kakvoću kriški rađeno je sa sortama jabuka Božičnica i Idared. Prosječna masa plodova od 107,59 do 151,71 gram dala je količina pokožice od 17,49 do 21,36%, sjemene lože od 13,94 do 17,01%, a iskoristivost plodova je od 49,96 do 54,59 % uz signifikantne razlike kod jabuka sorte Idared.

Rezane kriške obrađivane su prije postupka sušenja antioksidansom i to 0,1% otopina L-askorbinske kiseline. Sušenje kriški rađeno je konvekcijom zagrijanog zraka u dvije faze s različitim temperaturama. U prvoj fazi sušenja temperatura zraka od 80,37 do 83,90 ^{0}C zagrijala je kriške na 45,28 ^{0}C - 46,18 ^{0}C. Prosječna brzina zraka za sušenje iznosila je 1,98 m/s, a vrijeme sušenja od 58 do 73 minute za 229,6 - 275,0 grama uzorka. U drugoj fazi sušenja temperatura zraka od 65,25 do 70,90 ^{0}C zagrijala je kriške na 40,06 ^{0}C - 42,15 ^{0}C. Uz brzinu zraka od 1,85 m/s vrijeme sušenja u toj fazi je od 92 do 114 minute.

Količina suhe tvari u kriškama iznosila je 12,36-15,60%, a nakon sušenja 82,59-84,61 %. Krivulje sušenja za istraživane sorte modelirane su jednadžbom linearne regresije bez signifikantnih razlika, a jednadžba glasi:

$$y = 88{,}0627 + (-0{,}4281 \times \text{min})$$

uz koeficijent determinacije

$$r = -0{,}9812;\ R^2 = 0{,}9628 \text{ i } s_x = 4{,}33.$$

Određivanje kakvoće svježih i osušenih kriški rađeno je kemijskim analizama, senzoričkim ocjenjivanjem, te rehidratacijskim omjerom.

Testiranjem razlika u količini suhe tvari i saharoze između svježih i osušenih kriški ustanovljene su statistički signifikantne razlike.Testiranjem razlika u količini L- askorbinske kiseline, vrijednosti pH i ukupne kiselosti između svježih i osušenih kriški, nisu ustanovljene statistički signifikantne razlike

Jedan od najvažnijih pokazatelja kakvoće sušenja je rehidratacijski omjer koji je iznosio 4,03 do 4,90 bez signifikantnih razlika.

Testiranjem razlika u senzoričkim vrijednostima boje između osušenih kriški ustanovljene su statistički signifikantne razlike kod sorte jabuka Božičnica.

KLJUČNE RIJEČI

konvekcija, sušenje, Božičnica, Idared, kriške

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INTRODUCTION

Convective drying is one of the oldest procedures of fruit preservation.

Drying helps to increase the concentration of sugars and other constituents, as well as osmotic pressure which goes up to such an extent that the feeding of microorganisms is rendered difficult, almost impossible.

Drying of sliced apples disrupts their original organoleptic properties and changes their structure and nutritive values.

Dried apples are used in the production of baby food, as well as an addition besides cereals in the production of high energy level foodstuffs.

Winter varieties of Idared and Božičnica apples were exposed to drying. Idared is a leading variety of apples which, according to its chemical and organoleptic properties, falls into the category of industrial varieties. The second variety under research is called Božičnica and is an autochtonous Croatian variety which can be found in north-western regions of Croatia, mostly in small orchards and home gardens. The storing properties and chemical composition of this variety have given rise to researches into its preservation by drying.

REFERENCES

Preservation by drying is based on xeroanabiosis (from Greek xeros = dry, anabiosis caused by drying), that is, osmoanabiosis which functions as drying up to a certain water level in apples that is still sufficient for the activity of microorganisms. The basic principle of this manner of preservation is water evaporation which is a prerequisite for the normal metabolism of microorganisms. Water content in a fresh apple varies from 83 to 85% (Smock and Neubert, 1950), and it can be reduced by drying to 8 – 30% (Burić and Berki, 1978).

Convective drying performed under controlled conditions is one of the most widespread ways of drying in industry. It is carried out in a closed space – a dryer – where the air is heated and directed through the layer of a material.

Suitable for drying are those apples which have a lighter flesh and contain more acids, as well as a balanced ratio of sugars and acids in a finished product. According to some references (Smock et al. (1950), Gliha R. (1978), autumn and winter varieties are the most industrially processed of all due to their chemical and organoleptic properties, and because they bear fruit in abundance. Bigger fruits are used for drying, cut into slices, cubes, strips or as powder, while less developed ones are processed into jams, soft drinks or fruit mashes.

The preparation of a raw material for drying begins with cleaning and removal of mechanical impurities, after which the epidermis is separated by means of a mechanical, chemical or a combined treatment. Seed cases are removed from the cleaned fruits which are then cut into different shapes and thicknesses, namely rings and slices being 8 – 10 mm thick and cubes 6 mm, 10 mm, 16 or 20 mm thick (Burić and Berki, 1978; Vešnik et al., 1988). Apples can be cut into slices and strips (Nevenka Vrač, 1990).

Drying of apples is carried out by means of air which has a certain temperature, humidity and speed. According to references, apples are dried at two temperature levels.

During the first stage, drying air temperatures vary from 70 to 90.5^{0}C (Burić and Berki, 1978; Wilhelm et al., 1981; Goffings, 1987; Chiang and Petersen, 1987; Nevenka Vrač, 1990), while in the second stage they differ from 50 to 65.5^{0}C (Burić and Berki, 1978; Wilhelm et al., 1981; Goffings, 1987).

Air-flow speed also has an effect upon a drying process since higher air speeds induce a faster exchange of humidity and heat between the sample and the air. According to references, the speed of drying air varies from 1.3 to 3.0 m/s (Goffings, 1987; Chiang and Petersen, 1987; Karathanos et al., 1995).

The system of drying we choose has an impact upon hornlike parts, that is, shrinking of a sample, as well as on its test volume density, the openness of its structure and its rehydratation properties (Lovrić, 1991).

A dried product must satisfy certain organoleptic requirements, such as a uniform shape and even dimensions, both in a dried condition and after rehydration or cooking.

Colour is considered to be one of the most important parameters of the quality of a dried fruit. The assessment of a dried fruit's flavour and smell is primarily aimed at determining their strength, that is, the presence of any other taste or smell that are not typical of a particular variety.

Rehydration or the power of water absorption is an important indicator of a dried product's quality.

MATERIALS AND METHODOLOGY

The fruits of the investigated varieties were picked at optimal harvest times in different areas, as follows:

The apples from moderately continental cultivation areas were used in experiments A and D, whereas experiments B and C involved the fruits from more humid regions.

Apart from dry matter content, also analysed in the experiments were the amount of saccharose, pH values, the level of L-ascorbic acid and the overall acidity (expressed in percentage terms of malic acid).

Drying of apple slices was carried out in two stages, at different air temperatures. In the course of the first stage, those temperatures varied from 80 to 90^{0}C, whereas in the second phase they differed from 65.25 to 70.90C. The peeled fruits were cut into 6 – 8 mm thick slices, and the inactivation of enzymes was conducted by means of the water solution of 0.1% L – ascorbic acid whose temperature was 15^{0}C.

Label	Experiment A	Experiment B	Experiment C	Experiment D
Variety	Božičnica	Božičnica	Idared	Idared
Cultivation area	Orchard I	Orchard II	Orchard I	Orchard I
Number of samples	6	5	6	6

The samples were weighed on the Mettler PN 1210 measuring device, while the process of drying was followed on the Tehtnica 6000 balance. The indication of the surrounding air and the air in the dryer was done by Pt-100 sounds, with some additional digital measurements.

The slices were exposed to drying up to the water content of 16 to 20%. Then they were left for one day in a closed glass container to make the moisture uniform. After that they were packed into polyethylene bags and put in cold storage at the air temperature of 5^0C and the relative air humidity of 60%.

The basic chemical composition of the samples, as well as their rehydratation and organoleptic properties were analysed after drying.

After the dried apple slices had been stored for six months, their quality and the basic chemical composition were assessed together with their rehydratation and organoleptic characteristics.

RESULTS AND DISCUSSION

The research showed a higher level of starch in Božičnica apples, while the amount of soluble dry matter (refractometric value) they contained varied from 15.4 to 16.2%. Besides a satisfactory taste (ripe enough to be eaten) and a typical appearance, the apples also had a suitable quality which is in accordance with the references (Gliha, 1978; Pavičić, 1982 and 1987) and which proves that Božičnica and Idared apples were picked at optimal harvest times. The best quality fruits were put in cold storage where the air temperature was maintained at 0 to 2^0C and the relative air humidity from 90 to 92% (Gliha, 1978; Pavičić, 1982; Lenart, 1992 and 1993). After five months, the fruits were less hard and the starch completely desomposed. The soluble dry matter that was measured refractometrically was reduced, varying from 15.6 to 16.0%, which is a consequence of a slower continuation of metabolic functions in the cold store. Therefore, the results of the analyses show that the fruits were ripe enough to be eaten.

Since the average sample weight prior to drying differed from 107.59 to 151.71 g, the fruits were, judging by the references (Gliha, 1978), of an appropriate size and thus suitable for processing. On average, Idared apples had the biggest test weight; also, they varied in size less than Božičnica apples and some significant differences were found out after testing the variations in fresh fruits' weight.

The smallest amount of epidermis was measured in Idared apples, varying from 17.49 to 21.36%. After testing the differences in the level of epidermis, no significant variations were established between the investigated varieties.

The smallest amount of seed cases was also measured in Idared apples; on average, they differed from 13.94 to 17.01%, without any statistically significant differences.

The quantity of the measured slices varied from 49.96 to 56.30%, with some statistically significant differences in Idared apples.

The drying of the apple slices was carried out in two stages, at different air temperatures. Then they were cooled by the surrounding air. Since the dryer was set up within a laboratory, the air inside it had an effect on the drying conditions.

The average temperature of the surrounding air varied from 20.8 – 22.9^0C, while the relative air humidity differed from 45.5% to 62.15% on average. Testing of differences between the surrounding air temperature and the relative air humidity showed no statistically significant variations.

In the first stage of drying, the apple slices were exposed to the air temperature varying from 80.37 to 83.90^0C, whereas during the second stage it differed from 65.25 to 70.9^0C, showing no statistically significant differences.

The average heating of the slices in the course of the first stage varied from 45.28 to 46.18 ^{0}C, whereas in the second stage it was from 40.06 to 42.15 ^{0}C, without any statistically significant differences between the investigated varieties.

The average drying time varied from 195 to 219 minutes, without any statistically significant differences between the varieties under research.

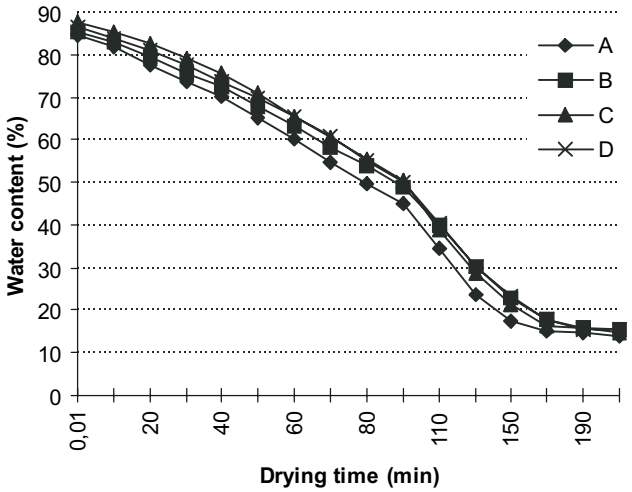
The statistical analysis of all the drying speed curves was modelled by a linear drying equation. In testing the results with the probability of 99.99%, the coefficient of determination (R^2) and the coefficient of correlation (r) were higher in the linear equation than in other curves (exponential, reciprocal and multiple).

A common drying equation reads as follows:

$$y = b + (- a\ x)$$

where y = drying speed (kg of water/h)
a = coefficient of direction (at drying "-")
b = moisture of sample (%)
x = drying time (in minutes).

Graph 1. shows the drying speed curves of the investigated varieties.



Graph 1. Drying curves of Božičnica (A,B) and Idared (C,D) apples, cut into slices

The analysis of all the points of measurement on 23 curves resulted in the following linear equation of the drying speed:

$y = 88.0627 + (- 0.4281x * \text{minutes})$

$r = - 0.9812\ R^2 = 0.9628$ and $s_x = 4.3344$

Testing of differences between the drying curves (water loss at a certain period of time) of the investigated varieties showed no statistically significant variations. The equation obtained shows a statistically significant correlation between the sample moisture and the drying time. The coefficients of determination (R^2) and of correlation (r) are very high.

Physical and chemical composition of fresh and dried slices, and of slices after storage

Tables 1-5 show the average chemical composition of the investigated varieties.

Testing of dry matter content in fresh and dried slices showed some statistically significant differences.

Testing of the amount of saccharose in fresh and dried apple slices showed some statistically significant differences.

Testing of pH values in fresh and dried slices showed no statistically significant differences.

Testing of the amount of L – ascorbic acid in fresh and dried slices showed no statistically significant differences.

Testing of overall acids in fresh and dried slices showed no statistically significant differences.

Rehydration ratio

The rehydration ratio of dried slices varied from 4.03 – 4.90, while after storage it differed from 3.71 to 4.23, with some statistically significant differences.

Organoleptic colour evaluation

The organoleptic colour evaluation of dried slices varied from 2.8 to 3.60, with some statistically significant differences between the investigated varieties.

Table 1. Dry matter content in apple slices (in percentage terms)

Experiment	Fresh slices	Dried slices	Stored slices
A	16.33	82.72	83.42
B	15.56	82.59	83.31
C	15.73	83.16	83.78
D	15.91	84.61	84.84

Table 2. Content of saccharose in apple slices per dry matter (in percentage terms)

Experiment	Fresh slices	Dried slices	Stored slices
A	9.82a	5.21a	5.88a
B	5.58ab	2.86ab	2.96ab
C	7.60bc	6.29b	6.35b
D	10.36c	6.53	6.58

(a,b,c) – significant differences P = 5%

Table 3. pH values in apple slices

Experiment	Fresh slices	Dried slices	Stored slices
A	3.74	3.89c	3.78c
B	3.68	3.91a	3.81a
C	3.65	3.82ab	3.71ab
D	3.69	4.03bc	3.94bc

(a,b,c) – significant differences P = 5%

Table 4. Amount of L – ascorbic acid in apple slices mg/100 g

Experiment	Fresh slices	Dried slices	Stored slices
A	2.87b	1.83ab	1.79a
B	3.45	2.57a	2.40ab
C	3.89a	3.59	3.43b
D	3.94ab	4.01b	3.62

(a,b,c) – significant differences P = 5%

Table 5. Amount of overall acids expressed in percentage terms of malic acid

Experiment	Fresh slices	Dried slices	Stored slices
A	2.99c	1.46a	1.43
B	2.93a	1.43	1.44a
C	3.52ab	1.49b	1.50ab
D	3.96bc	1.92ab	1.86b

(a,b,c) – significant differences P = 5%

After storage, the average colour evaluations varied from 2.4 to 3.6, with no statistically significant differences between the investigated varieties.

CONCLUSION

1. The products obtained after drying Božičnica and Idared apples showed some significant differences with regard to their organoleptic, chemical and physical properties. Idared apples received higher grades for the organoleptic properties of their flesh, colour, smell and taste.

   Dried Idared apples showed significantlly better chemical and physical properties as regards the amounts of saccharose, L – ascorbic acid and overall acids, as well as their rehydration ratio values.

   Idared apple dried slices also proved to be more durable during storage.

2. The exploitability of the raw material for the production of dried products varied from 15.71 to 17.71 %.

3. The burdening of the plate with the raw material varied from 4.3 to 5.2 kg per one square metre.

4. The achieved rehydratation ratios between fresh and dried samples (M1/M2) varied from 5.65 to 6.60.

5. In the course of the research, the following parameters were obtained:

- air temperature in the first stage varied from 80.37 to 83.9^{0}C;
- air temperature during the second stage differed from 65.25 to 70.9^{0}C;
- heating of the slices in the first stage was from 45.28 to 46.18^{0}C;
- heating of the slices in the second stage was from 40.06 to 42.15^{0}C;
- air speed varied from 1.85 to 1.98 m/s.

6. The drying equations that were obtained are as follows:

- for Božičnica apples
  y = 86.7258 + (- 0.4323x * minutes);
- for Idared apples
  y = 89.8789 + (- 0.4347x * minutes);
- for both varieties
  y = 88.0627 + (- 0.4281x * minutes)

where r = - 0.9812
R^2 = 0.9628
s_x = 4.33

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