Bulletin of the *Transilvania* University of Braşov
Series II: Forestry • Wood Industry • Agricultural Food Engineering • Vol. 9 (58) No.1 - 2016

EXPERIMENTAL RESEARCHES CONCERNING THE OPTIMIZATION OF THE DURATION OF THE DRYING PROCESS FOR THE APPLES CONSERVATION

Gheorghe C. BRĂTUCU[1] Andreea L. MARIN[1]
Dan I. PĂUNESCU[1]

Abstract: *This paper presents the results of the experimental research on optimizing the duration of the dehydration process of sliced apples and their conservation. On this purpose were considered three possibilities: choosing the apples dimensions (diameter 40, 50 and 70mm), the way of their slicing (halves, quarters and slices of 5mm and 10mm thickness) and setting the enclosure temperature (30°C, 40°C, 50°C and 60°C). The criteria for assessing the quality of dehydrated products took into account the preservation of the vitamin C and keeping their colour at a very high commercial aspect.*

Key words: *apple, dry curing, duration of dehydration, optimization.*

1. Introduction

The preservation by drying of fruit and vegetables was a widespread activity in households in Romania in the past. These products represented valuable food supplements for the population outside the timeframes in which they could not eat fresh products [1]. High energy consumption and the existence of the fresh products in all seasons in the market diminished the interest for the conservation by drying of those products in small peasant farms. The development of more refined equipment and the diversity of uses (soups, pastry industry etc.) kept the attention on the conservation by drying of fruit and vegetables [2]. This paper shows the results of the optimizing of the drying time for the conservation of apples, fruit that have a great tradition and culture conditions in Romania [3]. The research on dehydration as a way for the conservation of agricultural products is conducted globally and aimed at optimizing the quality of finished products, energy consumption and drying duration [6], [7], [8], [10].

2. Materials and Methods

Optimization of the drying process is carried out by:

[1] Department for Engineering and Management in Food and Tourism, *Transilvania* University of Brasov, 148 Castelului Street, Brasov, 500014, Romania;
Correspondence: Gheorghe C. Brătucu, email: gh.bratucu@unitbv.ro.

- slicing at the minimum size accepted by the required quality of the finished product;
- using the highest temperature of the drying agent, which does not affect final product quality;
- choice of products subject to the minimum dimensions drying imposed in accordance with its quality finished products.

Materials used in experimental research were: apples, drying equipment, instruments and apparatus for weighing samples and determining the moisture content [11] and vitamin C etc. Experimental investigations were conducted in laboratories of the Faculty of Food and Tourism of the Transilvania University of Brasov.

•Apples are part of the Golden Delicious variety, which are characterized by medium vigour, late blooming period, the average size of the fruit (160g), spheroid-conical shape, yellow, great taste and ripen in October (www.pepinieraszekely.ro).

• Drying chamber is part of the laboratory equipment used for experimental research for the drying of agricultural products. Precise Model AC 60 (www.precisa.ro) is a mini-dryer with forced ventilation and temperature control between +50...250°C. In general, this model is used not only for determining the water content and dry matter produced by heating them at 105°C for sterilization at high temperatures, but also for the drying of relatively small amounts of vegetable products at lower temperatures.

• Hygro Thermo Anemometer VT 300 300 (www.kimo.fr) is a multi-purpose tool, compatible with all SMART PRO probes and all type K thermocouples. SMART PRO probes are supplied with a calibration certificate, so that when they are connected to this device it displays the date of last calibration. All probes are automatically recognized when they are connected and interchangeable.

• Fluke 568 infrared Thermometer (www.fluke.ro) is a safe and effective means of obtaining information about temperature. It can be used to determine the temperature that emits electromagnetic waves of different surfaces, such as walls, fruit, vegetables etc.

• Professional scales SARTORIUS LC 820 (www.Sartorius.dataweigh.com) whose technical characteristics are: capacity, 820g; division, 0.01g; linearity, 0.01g; calibration mass, 500g.

Qualitative restrictions imposed on dewatering process of apples refers to keeping the colour of finished products as close as the fresh ones and the nutrient content, expressed by the content of vitamin C, in accordance to the minimum sizes of the slices requested by the destination of the finished products [4].

3. Conduct of the Experimental Research

The main stages of experimental research are given below:

•**Sorting the apples**: the size categories chosen are those with diameters of 40, 50 and 70 mm.

•**Cutting the apple:** the system is the same for all dimensions of the apples' slicing, namely: cutting in halves; cutting into quarters; slicing at a 5mm thickness; slicing ae a 10mm thickness.

•**Determination of the vitamin C content of fresh apples.**

The vitamin C content was determined using iodometric method, both for fresh products and for dried products.

The method is based on the oxidation of the ascorbic acid with iodine in excess. As oxidant may be used iodine generated in situ by the reaction of iodate with potassium iodide. Chemically, the vitamin C is the ascorbic acid [9].

The vitamin C content (mg/ 100g) is

calculated using the following equation:

$$0.352 \cdot \left(V_p \cdot V_m\right) \cdot 100 \cdot \frac{d}{m} \qquad (1)$$

Where: V_p is the volume of solution used in titration KIO_3 sample, in *ml*; $V_m = 0.3ml$ sample volume control; d - dilution volume $d = 25ml$; m - sample mass $m = 0.5g$.

For fresh apple, $V_p = 1.5ml$ and vitamin C content is:

$$0.352 \cdot (1.5 \cdot 0.3) \cdot 100 \cdot \frac{25}{0.5} = 792\ [mg/100g\ product] \qquad (2)$$

•Weighing fresh produce before placing in the drying room.

•Timing the duration of the drying process, depending on the size of the apples, the method of slicing and the temperature of the drying agent.

A. The experimental research of the dehydration process of the apples with the diameter 70mm.

•Apples of 70mm diameter, dried at 30°C, cut into 2 halves; Drying time: 48 hours.

The results are shown in Table 1. The final appearance of the sample is shown in Figure 1.

Table 1

The weighing program and humidity values

Hour	Weight [g]	Humidity [%]
13.00	154.10	95.62
16.00	147.68	91.55
20.30	140.37	86.91
8.30	128.01	79.07
11.30	125.35	77.38
14.00	122.42	75.53
16.45	119.37	73.59
21.15	115.12	70.90
8.00	102.60	62.96

Fig. 1. *Aspect of the sample after drying*

Because the moisture content of the sample was reduced by only 30% over a period of 48 hours, it is apparent that drying at 30°C for apples with a diameter of 70mm and cut in 2 halves is not effective taking into account the total time of the drying process, especially due to a high energy consumption.

• Apples of 70mm diameter, dried at 30°C, cut into 4 quarters; Drying time: 47 hours and 30 min.

The results are shown in Table 2. The final appearance of the sample is shown in Figure 2.

Table 2

The weighing program and humidity values

Hour	Weight [g]	Humidity [%]
13.00	138.41	91.69
17.00	126.82	83.82
21.00	114.65	75.56
8.30	97.17	63.69
11.00	93.21	61.01
14.00	88.98	58.13
18.00	84.86	55.34
22.00	80.88	52.64
8.30	62.52	40.17

Fig. 2. *Aspect of the sample after drying*

Because the humidity of the sample has not reached the value of keeping the product, which must be below 20% [5], although the drying time reached 48 hours and 30 minutes, it is apparent that the drying process at a temperature of 30°C of the apples of 70mm diameter, cut into quarters is not efficient as regards the energy consumption.

•Apples of 70mm diameter, dried at 30°C, cut into slices of 5mm; Drying time: 45 hours.

The results are shown in Table 3. The final appearance of the sample is shown in Figure 3.

Table 3

The weighing program and humidity values

Hour	Weight [g]	Humidity [%]
14.00	130.39	82.63
15.30	105.7	65.52
20.30	81.83	48.98
8.30	43.56	22.45
11.30	38.00	18.60
14.00	35.14	16.62
17.30	34.45	16.14
21.30	33.21	15.28
9.00	32.56	14.83

Fig. 3. *Aspect of the sample after drying*

Considering that after 48 hours and 30 minutes the humidity of the sample has reached a value of 14.83%, the optimum conservation of the product, it is apparent that drying at the temperature of 30°C for apples of 70mm diameter, cut into slices of 5mm is superior in terms of the quality of products but less effective in terms of the length of the drying process.

•Apples of 70mm diameter, dried at 30°C, cut into slices of 10mm; Drying time: 45 hours.

The results are shown in Table 4. The final appearance of the sample is shown in Figure 4.

Table 4

The weighing program and humidity values

Hour	Weight [g]	Humidity [%]
13.00	133.26	88.81
17.00	118.37	78,31
21.00	103.16	67.58
8.30	69.58	43.90
11.00	60.83	37.73
14.00	52.42	31.80
17.00	44.26	26.04
21.30	35.91	20.15
8.3 0	30.89	16.61

Fig. 4. *Aspect of the sample after drying*

Because after 48 hours and 30 minutes the humidity of the sample reached a value of 16.61%, the optimum for conservation of the product, it is apparent that drying at the temperature of 30°C of apples of 70mm diameter and 10mm sliced is superior in terms of the quality of products, but less efficient in terms of the length of the drying process.

•Apples of 70mm diameter, dried at 40°C, cut into slices of 5mm; Drying time: 31hours.

The results are shown in Table 5. The final appearance of the sample is shown in Figure 5.

Table 5

The weighing program and humidity values

Hour	Weight [g]	Humidity [%]
11.00	86.64	78.93
14.00	66.08	58.52
18.00	46.51	39.09
22.00	30.62	23.31
8.00	22.53	15.28
12.00	22.09	14.85
14.00	21.98	14.74
16.00	21.92	14.68

Fig. 5. *Aspect of the sample after drying*

Because the humidity of the sample after 31 hours reached a value of 14.68%, the optimum conservation of the product, it is apparent that drying at the temperature of 40°C of apples of 70mm diameter and cut into 5mm slices is of high quality and efficient in terms the duration of the drying process.

•Apples of 70mm diameter, dried at 40°C, cut into slices of 10mm; Drying time: 31 hours.

The results are shown in Table 6. The final appearance of the sample is shown in Figure 6.

Considering that the humidity of the sample after 34 hours reached the value of 12.42%, the optimum for conservation of the product, it is apparent that drying at the temperature of 40°C of apples with a diameter of 70mm and cut into 10mm slices is of superior quality and efficient in terms of the duration of the drying process.

Table 6

The weighing program and humidity values

Hour	Weight [g]	Humidity [%]
11.00	97.52	83.49
13.30	84.24	71.22
17.00	68.92	57.07
21.00	53.45	42.78
8.00	24.37	15.92
13.00	21.41	13.19
16.00	20.87	12.69
19.00	20.58	12.42

Fig.6. *Aspect of the sample after drying*

•Apples of 70mm diameter, dried at 50°C, cut into slices of 5mm; Drying time: 28 hours.

The results are shown in Table 7. The final appearance of the sample is shown in Figure 7.

28 hours reached a value of 14.37%, the optimum for conservation of the product, it is apparent that drying at the temperature of 50°C of apples with a diameter of 70mm, cut into 5mm slices is of appropriate quality and effective in terms of the duration of the drying process.

Table 7

The weighing program and humidity values

Hour	Weight [g]	Humidity [%]
13.00	69.03	64.31
16.00	54.31	49.57
18.00	45.86	41.12
20.00	33.64	28.88
8.00	19.22	14.45
10.00	19.20	14.43
12.00	19.17	14.40
14.00	19.14	14.37

Fig. 7. *Aspect of the sample after drying*

Because the humidity of the sample after

• Apples of 70mm diameter, dried at 50°C, cut into slices of 10mm; Drying time: 31 hours.

The results are shown in Table 8. The final appearance of the sample is shown in Figure 8.

Table 8

The weighing program and humidity values

Hour	Weight [g]	Humidity [%]
13.00	92.77	82.24
16.00	81.36	71.58
18.00	69.38	60.38
22.00	54.43	46.41
8.00	26.25	20.06
11.00	22.29	16.36
13.00	18.37	12.70
15.00	18.28	12.61
17.00	18.16	12.50

Because the humidity of the sample after 31 hours reached a value of 12.50%, the optimum for conservation of the product, it is apparent that drying at the temperature of 50°C of apples with a diameter of 70mm and cut into 10mm slices is of appropriate quality and efficient in terms the duration of the drying process.

Fig. 8. *Aspect of the sample after drying*

• Apples of 70mm diameter, dried at 60°C, cut into slices of 5 mm; Drying time: 26 hours.

The results are shown in Table 9. The final appearance of the sample is shown in Figure 9.

Table 9

The weighing program and humidity values

Hour	Weight [g]	Humidity [%]
13.00	69.39	62.87
16.00	58.73	52.50
18.00	45.26	39.39
20.00	36.17	30.54
8.00	17.90	12.76
10.00	17.86	12.72
12.00	17.82	12.68

Because the humidity of the sample after 26 hours reached a value of 12.68%, the optimum conservation of the product, it is apparent that drying at the temperature of 60°C of apples with a diameter of 70 mm and cut into 5 mm slices is less appropriate in terms of the quality, but effective in terms of the drying duration.

Fig. 9. *Aspect of the sample after drying*

• Apples of 70mm diameter, dried at 600C, cut into slices of 10mm; Drying time: 26 hours.

The results are shown in Table 10. The final appearance of the sample is shown in Figure 10.

Table 10

The weighing program and humidity values

Hour	Weight [g]	Humidity [%]
12.00	81.70	72.03
15.00	69.63	60.73
18.00	58.74	50.53
21.00	42.31	35.14
8.00	19.01	13.32
10.00	18.97	13.28
12.00	18.92	13.24

Fig. 10. *Aspect of the sample after drying*

Because humidity of the sample after 28 hours reached a value of 13.24%, the optimum for conservation of the product, it is apparent that drying at the temperature of 60°C for apples with a diameter of 70 mm, 10mm cut into slices is less appropriate in terms of the quality, but effective in terms of the drying duration.

B. the experimental research of the dehydration of the apples of a 40mm diameter.

Experimental researches followed a similar program as for apples with a diameter of 70mm. Due to the limited space available is presented below only the result of a single sample, which was deemed representative.

•Apples of 40mm diameter, dried at 60°C, cut into slices of 5mm; Drying time: 24 hours.

The results are shown in Table 11. The final appearance of the sample is shown in Figure 11.

Table 11

The weighing program and humidity values

Hour	Weight [g]	Humidity [%]
14.00	61.42	52.10
16.00	53.79	44.83
18.00	48.37	39.66
20.00	35.26	27.16
8.00	20.87	13.44
10.00	20.79	13.36
12.00	20.73	11.21

Fig. 11. *Aspect of the sample after drying*

Because the humidity of the sample after 24 hours reached a value of 11.21%, the optimum for conservation of the product, it is apparent that drying at the temperature of 60°C of apples with a diameter of 40mm and cut into 5mm slices is less appropriate in terms of the quality, but very effective in terms of the duration of the drying process.

C. The experimental research of dehydration of the apples with the diameter 50mm

Experimental researches followed a similar program as for apples of 70mm diameter. Due to the limited space available is presented below only the result of a single sample, which was deemed representative.

•Apples of 50mm diameter, dried at 60°C, cut into slices of 5mm; Drying time: 25 hours.

The results are shown in Table 12. The final appearance of the sample is shown in Figure 12.

Table 12

The weighing program and humidity values

Hour	Weight [g]	Humidity [%]
13.00	66.29	61.41
16.00	58.18	53.04
19.00	45.39	39.84
22.00	37.21	31.40
7.00	18.59	12.18
9.00	18.53	12.12
11.00	18.46	12.05

Fig. 12. *Aspect of the sample after drying*

Because after 25 hours of sample humidity value reached 12.05%, best to preserve the product, it follows that drying at 60°C apples diameter 50mm, sliced 5mm less appropriate quality but very effective in terms of the duration of the drying process.

•Determination of vitamin C of dehydrated apples

The vitamin C content (mg/ 100g) is calculated using the equation (1)

If apple dried at 30°C, $Vp = 4.5ml$ and vitamin C content is:

$$0.352 \cdot (4.5 \cdot 0.3) \cdot 100 \cdot \frac{25}{0.5} = \\ = 2{,}376[mg/100g\ product] \quad (3)$$

Similarly, the vitamin C content is determined at the temperatures of 40°C, 50°C and 60°C. By increasing the temperature at which the product is drying, vitamin C content decreases. It appears that this aspect should be taken into account when the drying temperature is set. Thus, in turn it will be a factor in the optimization of the duration of the drying process

It is noted that the change in the content of vitamin C is inversely proportional to the reduction of the moisture content, respectively, as the water content is reduced, the amount of vitamin C is higher, although globally there is a loss of vitamin C.

4. Interpretation of Data Obtained from Experimental Researches

•Optimization of the duration of the drying process by choosing the size of slices, in case of the apples of 70mm diameter

In Figure 13 are shown the influence of the slicing system on the drying duration of the apples with a 70mm diameter dried at a temperature of 30°C and the linear regression equation of the mass of samples.

It can be seen in the graph in Figure 13 that the shortest duration of about 45 hours was recorded in the case of apple slices of 5mm thickness and the moisture content registered the value of 14.83%. In the case of cutting apples in halves and quarters, the drying process was stopped after 48 hours

due to the inefficient energy consumption and a very long total drying time. As regards of the slices of 10mm thickness, the drying process was considered accomplished after 46 hours when the moisture content reached the value of 15.79%.

• ***Optimization of the drying process by choosing the size of the original product for apples drying, if sliced of 5mm thickness.***

For apples of all sizes, the shortest drying time was recorded when the temperature of the drying process was 60°C and apples sliced at a 5mm thickness, as shown in the graph in Figure 14.

By analysing the graph in Figure 14 it was found that the drying process of the sliced apple of a 40mm diameter was the fastest, at about 24 hours, in which the humidity of the sample reached a value of 11.21%, whilst the humidity of the sliced apple of 50mm diameter has come to a value of 12.05% after 25 hours, and that of a 70mm diameter at a value of 12.68% after 26 hours.

5. Conclusions

1. Apples subjected to dehydration were prepared by successive severing in halves, quarters and sliced at a 5mm and 10mm thickness. Temperatures at which the research was conducted were 30°C, 40°C, 50°C and 60°C, and the testing period was variable, depending on the matter of the optimal humidity required for storage.

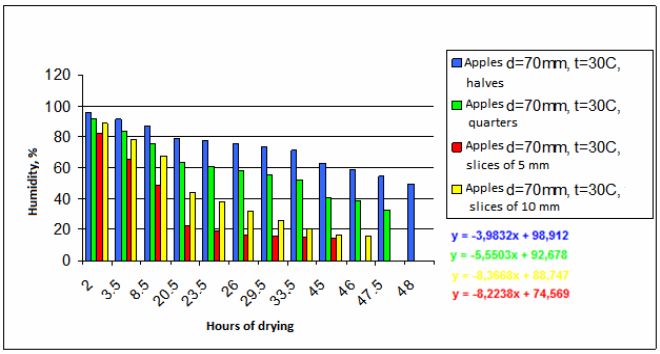

Fig. 13. *The influence of the system of slicing on the drying time in the case of apples with a diameter of 70mm dried at a temperature of 30°C*

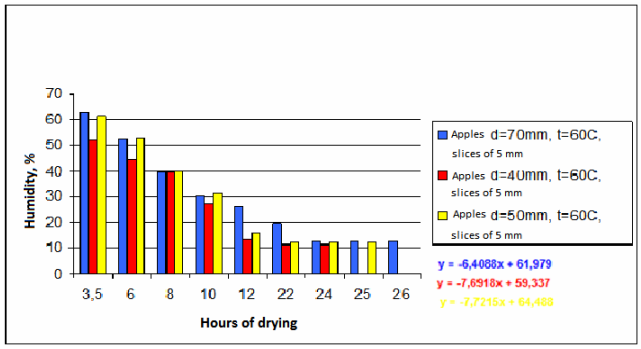

Fig. 14. *The influence of the initial dimension of the sample on drying duration in the case of apples slices of 5mm thickness, dried at a temperature of 60°C*

2. The qualitative assessment of fresh and dried products took into account the vitamin C content as the representative chemical compound, and the way in which the colour as a physical aspect was maintained. The content of vitamin C in fresh apples was 0.792 g/100g, and in dried apples at 30°C was 2.376 g/100g product. Obtain the concentration of vitamin C in similar masses of fresh or dried 2.2...2.4 times, although there is an overall loss of vitamin C by dehydration.

3. The colour of the dehydrated products had been greatly influenced by the temperature at which the dehydration process was conducted. At a temperature of 30°C, the colour was pleasant and close to the fresh produce, while at 60°C, the colour of products got browning.

4. In the case of 40°C, 50°C and 60°C temperatures the drying duration of the apples of 40mm diameter and sliced at a 5mm thickness, was of about 15…25% shorter than of the apples of 70mm diameter and sliced in an identical way.

References

1. Beceanu D., Chira A., Pascal I., 2003. Fruit, Vegetables and Flowers. Extending Methods of Preserving Fresh. Canned Vegetables and Fruits Extension. (in Romanian). Publishing House M.A.S.T. Bucharest.
2. Brătucu Gh., Marin A.L., Florea C.C, 2013. Research On Carrot Drying By Means Of Solar Energy. In: Bulletin of the Transilvania University of Brasov – Series II, vol. 6(55), no. 1, pp. 91-98.
3. Câmpeanu Gh., Neață G., Darjanschi G., 2009. Chemical Composition of the Fruits of Several Apple Cultivars Growth as Biological Crop. In: Notulae Botanicae Horti Agrobotanici Cluj-Napoca, vol. 37(2), pp. 161-164.
4. Epure D.G., Mitroi A., Udroiu A. et al., 2007. Influence of the drying parameters on quality of dried products. Sustainable Agriculture– Solutions & Perspectives. INMATEH 2007-III. no. 21. Bucharest.
5. Gaceu L., Csatlos C., Brătucu Gh., 2000. Computer aided optimisation of grain dryers. International Computer Science Conference, University of Miskolc, Hungary.
6. Marin A.L., Brătucu Gh., 2010. Research Regarding on the Balance of Masses in Conservation by Drying of Vegetables and Fruits. In: Journal of EcoAgriTourism, vol. 6, no. 2(19). Braşov.
7. Marin A.L., Brătucu Gh., 2013. Research regarding Energy Optimization in the Dehydration Process of Tomatoes. In: Bulletin of the Transilvania University of Brasov – Series II, vol. 6(55), no. 1, pp. 77-84.
8. Mitroi A., Epure D.G., Udroiu N.A. et al., 2007. Contributions to configure ecological processes of drying agricultural products point of view of product quality and energetically. In: The 8th National Conference environmental protection through biotechnology, Braşov, Romania.
9. Moldovan P., Toşa M.I., Leț D. et al., 2006. Applications for Biochemistry Laboratory. Publishing House Napoca Star, Cluj-Napoca.
10. Răducanu P., Turcoiu T., Florea A., 1999. Thermo – Gaz – Dynamically Processes in Instalations for Drying and Storage for Agri-Foods Products. Tehnical Publishing House, Bucharest.
11. Voicu Gh., 2004. Aspects of the determination of moisture and powdery bulk materials with infrared devices. In: "Scientific Research in Terms of European Integration" National Conference. Brăila, Romania