Ann. For. Res. 66(1): 4191-4209, 2023
ISSN: 18448135, 20652445

ANNALS OF FOREST RESEARCH
www.e-afr.org

COMPARATIVE ANALYSIS OF THE PROCESSES OF DEHYDRATION AND LYOPHILIZATION OF STRAWBERRY (*fragaria*) AND APPLE (*MALUS*)

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Summary

The present work aims to perform a comparative analysis of the processes of dehydration and lyophilization of strawberry (fragaria) and apple (malus), collecting information from the variables of the processes, which will be carried out each process with a lyophilizer and a dehydrator, in which qualitative variables will be measured by an energy analyzer, which will obtain a much better response in the dehydration of fruits, with a value in consumption of kWh lower than that of lyophilization, and analyzing physicochemical characteristics through the use of laboratory techniques, in order to obtain moisture and ash content in percentages, the microbiological characteristics established by national regulations which were obtained total absence in the microbial load of E. coli and Salmonella, sensory characteristics are achieved without significant differences, which are performed by a five-point scalar hedonic analysis, a mass and energy balance was determined, in which there were much better yields when the fruit is dehydrated, with greater losses when the fruit is lyophilized, the cost-benefit balance was made to each process and a better result was obtained when the fruit is dehydrated, With a greater gain for each gram that was processed, so it is concluded that when performing dehydration will be obtained lower values of time, energy, weight loss, with better results when this is evaluated sensory, with greater benefits in terms of the balance of cost benefit, that is why dehydration is restarted in terms of lyophilization.

Palabras clave: DESHIDRATACION, LIOFILIZACION, MANZANA (*malus*), FRESA (*fragaria*) , ENERGIA, PROCESOS, SENSORIAL.

1. Introduction

The strawberry and the apple are products of high demand in the market, for its organoleptic characteristics, it can be consumed fresh, but there are certain times of the year in which there are overproductions, and this is where the fruit is wasted, so in the food industry methods have been developed to preserve fruits. Foods with a high water content, such as apples and strawberries that occur in Zone 3, have a boom in the market, and if they are marketed in different ways, they have a considerable increase at certain times of the year, in order to preserve these products to increase their value, when using conservation processes.

Dehydration is one of the oldest techniques, in which man has used for the preservation of food, on the other hand, it is a process that is commonly used in the agricultural industry, this process is based on removing water present from the fruit, which through a process in which the temperature is increased evaporates the water present in them, this method allows to preserve the product for longer of useful life, on the other hand it improves the transport reducing the costs of the same, and facilitates its storage (Cabascango, 2018, P.7)

Lyophilization is a method of drying fruits, which results in a fruit with a completely amorphous structure, this method consists of freezing the water present in the fruits, and dehydrating it by sublimating it. (Reyes, 2020, p.29).

In the methods and processes of conservation of fruits and vegetables, it has in itself many advantages, as well as disadvantages, speaking in itself nutritionally, expenditure of resources and energy of the processes, and economic cost, dehydration is known, and is a more traditional method, using temperatures both naturally or artificially, naturally it can be said that solar energy is used, This is a low energy expenditure, with greater economic efficiency, the lyophilization method is a process with greater complexity, it requires much more energy, in which it starts with freezing and sublimation under vacuum, up to five times more energy is consumed, representing a much higher cost, but the initial structure of the product is preserved, whether to lose essential oils, or volatile compounds, which would be lost in conventional dehydration, which nutritional characteristics, and organoleptic characteristics are lost.

1.1 Problem statement

The drying methods used in the most common fruits are dehydration and lyophilization lime has its origin in ancient times, they are used in foods that tend to be perishable, due to their high water content, it is here that microorganisms act, such as fungi, molds and bacteria, for them despite the

fact that there are other preservation methods such as freezing, In which the activity of enzymes decreases, this method can deteriorate the food, because when it freezes it produces ice crystals, and the oxidative phenomenon continues, and modifies them, in the same way the freezing causes the walls of the product to break, deteriorating it and reducing its harmless part.
That is why it is estimated that the most effective solution, in the process of eliminating the water present in the food, because it is one of the main causes of food spoilage, increasing the proliferation of microorganisms, according to Ocaña (2013, p.1) mentions that up to 20% of total fruit production can be lost in crops, and food preservation methods are no longer sufficient in Ecuador.

2. Objectives

2.1 General objective

Perform a comparative analysis of the dehydration and freeze-drying processes of strawberry (*fragaria*) and apple (*malus*).

2.2 Specific objectives

- Compare the dehydration and freeze-drying processes of strawberry (*fragaria*) and apple *(malus),* determining variables for each process.
- Analyze the physicochemical, microbiological and sensory characteristics of freeze-dried and dehydrated fruits.
- Determine an energy balance, cost benefit of the processes analyzed.

3. Methodology

3.1 Location and duration of the experiment

The present work was carried out in the laboratories of Biological Sciences and Bromatology of the Faculty of Livestock Sciences of the Polytechnic School of Chimborazo, located in the Panamericana Sur km 1 1/2 in the city of Riobamba, province of Chimborazo, Ecuador. The experimental work lasted 90 working days.

3.2 Experimental units

The experimental units of strawberry and apple were 250g for each fruit, which was performed 5 repetitions for each treatment, using a total of 10 experimental units for each fruit.

3.3 Fruit dehydration process

For the realization of the dehydration of the fruits, the best time of the drying curve was taken, and the drying process is carried out by the dehydration method described by (Michelis and Ohaco, 2014, p 62)

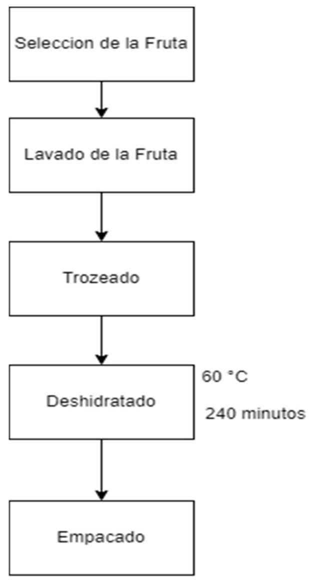

Figure 1: Fruit dehydration process
Conducted by: Neppas, Cristian, 2022

3.3.1 Process description

- **Fruit selection**

The apples with the highest quality should be selected, separating any type of fruit that has some type of physical damage.

- **Washing the fruit**

The fruit is washed with water, in order to remove any impurities from these

- **Chopped**

The fruit is cut into slices, thin to facilitate the dehydration of this

- **Dehydrated**

The cut fruit is placed in the trays of the dehydrator until it reaches the humidity and final weight

- **Packed**

Once the fruits are cold, they are packed in plastic covers and thus preserved.

4. Analysis and interpretation of results

4.1 Results of the Dehydration and Freeze-drying process

The results of the dehydration and lyophilization process are cited in Table 1, which shows the characteristics of the process variables.

Parameters	Dehydrated			Lyophilized			T. Cal	Prob.
	Media		Some. East.	Media		Some. East.		
Apple:								
Time, H	4,62	±	0,14	37,83	±	0,37	-186,66	0,0001
Temperature, °C	60,00	±	0,55	-52,2	±	1,3	178,04	0,0001
Weight loss, %	13,88	±	0,27	12,36	±	0,21	10,16	0,0001
Energy, KwH	0,64	±	0,000548	6,34	±	0,000548	-16454,48	0,0001
Strawberry:								
Time, H	5,93	±	0,137	37,68	±	0,37	-178,12	0,0001
Temperature, °C	60	±	0,548	-51,2	±	1,3	176,46	0,0001
Weight loss, %	10,65	±	0,214	8,39	±	0,505	9,23	0,0001
Energy, KwH	1,060	±	0,00055	3,150	±	0,0005	-6033,31	0,0001

DES. Est: Standard deviation
T. Cal: T calculado
Prob. > 0.05: There are no statistical differences.
Prov. < 0.01: There are highly significant differences

Table 1. Variables of dehydration and lyophilization processes
Made by: Neppas Caza, Cristian, 2022.

4.1.1 Time and temperature of dehydration by the two methods

Apple

In the dehydration of the apple required a time of 4.62 ± 0.14 hours, while when lyophilizing this time increased from 37 ± 0.37 hours, responses that are statistically different, on the other hand the temperature reported in the dehydrated apple was 60 ± 0.55 ° C , different result when the apple is lyophilized (-52.2 ± 1.3 ° C), that is to say that in the dehydrated apple there are values that are lower than the freeze-dried apple which denotes that when lyophilizing it is required up to ten times the time and temperature, these results have a relationship to the results by (Erdociain, 2020, p. 18) which obtains the best dehydration time of the apple is 240 minutes (4 hours), and a temperature of 60 ° C, has a relationship with (Adrian, 2020, p. 51) obtaining results in his work for the dehydration of the apple, when I use an electric oven at a temperature of 60 ° C for 4 hours, which is the best treatment to dehydrate the apple, these results keep a very similar value, So if you take a time or a temperature May, this could denature the product, so you should take the time and temperature of the dehydration method, because they present more real values that could be used, in the daily part of a producer either this small or medium.

Strawberry

The time obtained from the dehydrated strawberry was 5.93±0.137 hours, and a temperature of 60 ± 0.548 °C, which is a result that is increased when the strawberry is lyophilized, its value increases to a time of 37.68 ±0.37 hours, and a temperature that decreases from -51.2 ± 1.3 °C, these results are different from those obtained by (PRODAO, 2020, p. 20-24) in the lyophilization time was performed at 1200 min (20 hours) and a temperature of -40 ° C, agrees with (Quilumbaquin, 2019, p. 44) which performed the dehydration process at about 6 hours and a temperature of 60 ° C, there is a lower result compared to those obtained in the research carried out by (Alvarado, 2017, p. 33) that a time of 45 minutes and a temperature of 61.85 °C is used, therefore the dehydration method must be taken in time, because in this process it is used up to ten times less time and a temperature that would be easier to use by small producers.

4.1.2 Fruit weight loss

Apple

The weight loss of the dehydrated apple was 13.88 ± 0.27%, a result that was statistically equal to the freeze-dried apple (12.36 ± 0.31%), that is, from an initial weight of 250g they lost the weights already mentioned, these results that agree with (Adrian, 2020, p. 51) which mentions that the apple loses up to 90%, and you have 10% at the end of the process when the apple is dehydrated, similarly this result is related to (Sepúlveda et al., 2011: pp.423-427) which mention that the apple loses in the same way up to 90% of its weight, with a weight of 10% at the end of the process, this result also agrees with (PRODAO, 2020, p. 20-24) which has a loss of 84.22% of the total weight, which has a final weight of 15.88%, so the best result in weight loss is when the apple is dehydrated, so dehydrate the apple is re-food if it is required to have a greater weight at the end of the process.

Strawberry

The percentage of weight loss by the strawberry presents in its initial phase a weight of 250 g, so when it is dehydrated it had a final weight of 10.65 ± 0.214% result that was higher when the strawberry was freeze-dried 8.39 ± 0.505, these results are lower than those reported by (Quilumbaquin, 2019, p. 44), in which the strawberry lost up to 85.90%, that is, it had 14.10% at the end of the dehydration process, differs with (PRODAO, 2020, p. 20-24) which mentions that the weight loss of the strawberry is 94.22%, obtaining 5.78% in the end, a result equal to that obtained by (Alvarado, 2017, p. 33) in which 15% was obtained at the end of the freeze-drying process, the strawberry has a greater weight loss, due to the using process, and if you want to have a lower weight loss, dehydration should be used as a preservation method.

4.1.3 Energy used by processes

Apple

The amount of energy that was used in the process of total dehydration of the apple was 0.64 ± 0.0005 KwH, a result that increased up to six times when the apple was freezed, to 6.34 ± 0.0005 KwH, these values have a lot of difference when talking statistically, it is said that the process used in the apple will affect the expenditure required of energy, this result has a lot of difference in what was reported by (Castaño and Londoño, 2017: p.113) which has a consumption of the freeze dryer of 1,599 KwH, which despite being low consumption, uses half of the energy consumed compared to the energy of the work done, this is influenced by the time that the process lasts, that is, a certain amount of energy Kw per hour (KwH) is spent, it is related to what was mentioned by (Erdociain, 2020, p. 18), that I work with the apple dehydration process at a time of 240 minutes (4 hours), which is a time less than the traditional lyophilisate that is required up to almost a day of processing, In energy terms, there is a lower energy consumption when the fruit is dehydrated, and this being the best process when it is required to spend less energy in the process of preserving the fruits, and that producers need it.

Strawberry

The energy (KwH), which is required to be used in the total process, of dehydration is 1.060 ± 0.0006 KwH, result that is increased in the process of lyophilization of the strawberry, this result is 3.15 ± 0.0005 KwH, representing a significant difference, when speaking statistically, this result is reflected with what was mentioned by (PRODAO, 2020, p. 20-24) that says that the freeze-drying time of the strawberry should be done in 1200 min (20 hours), having a direct relationship in time per unit of energy consumed, on the other hand differs with (Alvarado, 2017, p. 33), in which the freeze-dried strawberry requires 10 KwH of energy, when less energy is required, The strawberry must be dehydrated, because it has a lower consumption, up to six times less compared to the consumption of the freeze-drying process.

4.2 Physicochemical, microbiological characteristics

Parameters	Dehydrated			Lyophilized			T. Cal	Prob.
	Media		Some. East.	Media		Some. East.		
Apple:								
Humidity, %	12,73	±	2,11	11,64	±	0,588	1,11	0,3310
Ash, %	2,06	±	0,27	2,01	±	0,062	0,49	0,6700
Strawberry:								
Humidity, %	14,99	±	0,35	12,740	±	0,454	8,78	0,0001

Ash, %	3,59	±	0,16	2,0860	±	0,104	17,62	0,0001

DES. Est: Standard deviation
T. Cal: T calculado
Prob. > 0.05: There are no statistical differences.
Prov. < 0.01: There are highly significant differences

Table 2. Physicochemical characteristics of dehydration and lyophilization of apple and strawberry
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4.2.1 Moisture content of dehydrated and freeze-dried apples

The relationship in the humidity of strawberries has no significance, statistically speaking, therefore, when the apple is dehydrated it has a moisture percentage of 12.73 to 2.11%, while when the apple is freeze-dried it has a moisture percentage of 11.64 to 0.588%, results that are different from (PRODAO, 2020, p. 20-24), in which he mentions that the freeze-dried apple reached a value of 5.88% humidity, but they are related to the results obtained by (Adrián, 2020, p.51) which mentions that the dehydrated apple reaches a moisture percentage of 9.95%, so the treatment used for drying the fruits, does not have much difference in moisture content.

4.2.2 Percentage of dried and freeze-dried apple ash

The ash content of the apple when dehydrated was 2.06 ± 0.26% while when using the lyophilizer this varied content of 2.0 ±0.062%, values that statistically are not different, which determines that the use of the dehydrator and lyophilizer does not affect the ash content, these values compared to what was obtained by (López et al., 2021: pp. 247-260), of the ash content of the apple there is an ash percentage of 4.36%, which are lower, on the other hand in the bromatological analyses obtained by (Amores, 2011) of a freeze-dried fruit with an ash content of 3.6% differ from the values obtained, this is because the composition of the fruits, In this case of the apple, infers in the content ashes.

4.2.3 Moisture content of dehydrated and freeze-dried strawberries

The dehydrated strawberry has a moisture percentage of 14.99 ± 0.35, while when performing the lyophilization process this decreases in the percentage of moisture to 12.70 ± 0.454, these results present statistical differences, it is agreed with (Alvarado, 2017, p. 33), which obtains in a strawberry with 15% moisture when it is dehydrated, and that has a lot of influence the type of dehydrator used, the results obtained differ with the work done by (Huaraca, 2011) which has a result in the strawberry of 12.12% moisture when it is dehydrated, and a percentage of moisture of 1.66% when it is lyophilized, unlike the percentage of moisture of the freeze-dried strawberry that reached a percentage of humidity of 15.78% in the work of (PRODAO, 2020, p. 20-24), these results differ in each type of work, by the type of process used, and the type of process will affect the final moisture content of the dried fruit, and to obtain a lower percentage of moisture from the fruits, lyophilization should be used.

4.2.4 Percentage of dried and lyophilised strawberry ash

The percentage of ashes that was obtained when the strawberry was dehydrated was 3.59 ± 0.35, a value that was reduced to 2.086 ± 0.104 when the strawberry was freezed, values that are statistically different, that is, the ash content differs when a different process is used, these values are different from those reported by (Huaraca, 2011), in which the strawberry reaches 4.14 ash content, the value increases when the strawberry is freeze-dried and reaches 4.37% ash content, values that are also different, therefore if you want to obtain a better ash content you should use the dehydration process.

4.3 Sensory characteristics

4.3.1 Sensory analysis of the apple

	Dehydration procedures			
Parameters	**Dehydrated**	**Lyophilized**	**Hcal**	**Prob.**
Appearance. 5 points	3,50	3,50	0,19	0,9143
	I like it moderately	I like it moderately		
Smell. 5 points	3,60	3,80	2,08	0,2857
	I like it moderately	I like it moderately		
Taste. 5 points	4,20	4,00	1,33	0,1429
	I like it moderately	I like it moderately		
Texture, 5 points	3,70	3,40	0,033	0,6571
	I like it moderately	I don't like or dislike it		

Hcal: Calculated value of the Kruskal-Wallis test
Prob. > 0.05: There are no statistical differences.
Proprob<0.05: There are significant differences
Prov. < 0.01: There are highly significant differences

Table 3. Sensory assessment of dehydrated and freeze-dried apple
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4.3.1.2 Appearance

In the process of assessing the appearance of the apple, whether it is dehydrated or lyophilized is not affected by any of the processes, statistically being the same and receiving all the rating of likes moderately, with a value of 3.50 for dehydration and lyophilization, establishing that the process of dehydration or lyophilization does not affect the assessment of appearance, these values could be influenced by the above (Moreno et al., 2012: pp. S201-S203), heat and timing affect how the fruit that is treated with the dehydration method will look, so it is said that the untrained panelists reflect that they do not find differences in the appearance of the apple either dehydrated or freeze-dried.

4.3.1.3 Odour

The valuation of the smell in the apple are 3.60 to 3.80 for dehydration and lyophilization respectively speaking, and does not present statistical differences, therefore it will not be influenced by the treatment used in it, this apple presents a rating of likes moderately, this value has a relationship for what was said by (Ayala and Calle, 2016: p.19), which says that the smell depends a lot on the type of fruit and components found in it, and no matter the method used to preserve the apple, the two methods will have the same assessment in appearance of the smell that each treatment presents.

4.3.1.4 Taste

The appearance of the flavor presented by the apple is the same and will not be affected by any of the processes of dehydration or lyophilization, being statistically equal, the organoleptic assessment of the apple has a value of 4.20 in dehydration and 4.00 in lyophilization, these results are related to what it describes (Huaraca, 2011, p.101) in which he mentions that the dehydrated strawberry has a more intense flavor, due to the temperature used in this, that is, it greatly affects the flavor of this, the results obtained in the present work, present an assessment of I like moderately, and the flavor of the apple will not be affected by any of the processes.

4.3.1.5 Texture

The organoleptic characteristics, in this case of the texture of the dehydrated and lyophilized apple, dehydration receives a level of liking of likes moderately, that is to say that the value is 3.70 compared to the value of lyophilization 3.40, with an assessment of I do not like or dislike it, but in the same way they do not present statistical differences, this is due to what he mentions (Moreno et al., 2012: pp. S201-S203), that heat and times have a lot of influence on the texture of dehydrated fruits, because there is a difference in the temperatures of the two methods, and water present in food is removed in a different way, in the end untrained panelists prefer in a certain way in the aspect of the texture of dehydrated mazana versus lyophilized.

4.3.2 Sensory analysis of strawberries

	Dehydration Procedure			
Parameters	**Dehydrated**	**Lyophilized**	**Hcal**	**Prob.**
Appearance. 5 points	3,60	3,80	2,08	0,2000
	I like it moderately	I like it moderately		
Smell. 5 points	3,60	3,90	0,19	0,7143

	I like it moderately	I like it moderately		
Taste. 5 points	3,40 I don't like or dislike it	3,30 I don't like or dislike it	0,08	0,9143
Texture, 5 points	3,70 I like it moderately	3,60 I like it moderately	0,02	0,9999

Hcal: Calculated value of the Kruskal-Wallis test
Prob. > 0.05: There are no statistical differences.
Proprob<0.05: There are significant differences
Prov. < 0.01: There are highly significant differences

Table 4. Sensory assessment of dehydrated and freeze-dried strawberries
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4.3.2.1 Appearance

The results obtained in the dehydrated strawberry are 3.6 value that is statistically different from that obtained in the lyophilization of 3.80, results that present an assessment of likes moderately, these values have influence as described by (Huaraca, 2011, p.101) in that time and temperature affect the appearance of dehydrated products, and the values obtained have no influence on the appearance of the strawberry and untrained panelists do not tend to Choose the strawberry that is processed with the two treatments.

4.3.2.2 Odour

The evaluation obtained of the smell of the dehydrated and freeze-dried strawberry, are not statistically different presenting a value of likes moderately, values that are supported by what was said by (Ayala and Calle, 2016: p.19) which mentions that the strawberry has characteristic odors of the fruit, due to its composition, and the appearance of this is not affected by the type of processing used.

4.3.2.3 Taste

The flavor of the dehydrated and freeze-dried strawberry has a lower value with respect to the other attributes, although they are statistically the same, presenting a value of I do not like or dislike, that is why (Tamba, 2015, p.4) mentions that sugars are one of the most important components of fruit flavor, generally the temperature of a process greatly affect the composition of it, But in both cases the panelists don't tend to prefer one over the other.

4.3.2.4 Texture

The texture of the strawberry does not present a statistical difference, there is a value of 3.7º for the dehydration process and a value of 3.60 in the lyophilization, values that represent a level of liking of likes moderately, this also has a lot of influence for what was mentioned by (Moreno et al., 2012: pp. S201-S203), in which he mentions that the temperature and time of processes have a lot of influence on the texture of the fruits Dry, that is, the differences in the temperature and time ranges of the processes is very different, but will not affect the final texture of the product.

4.4 Energy mass balance, cost benefit of products

Energy required for drying	
Treatment	Kw
Apple:	
Dehydration	0,3695
Freeze-drying	0,3383
Strawberry:	
Dehydration	0,04828
Freeze-drying	0,05305

Table 5. Energy required for the dehydration and freeze-drying of fruits by means of
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Apple

The value of energy calculated for the dehydration process was 0.3695 kW, a result that is similar to the lyophilizer, 0.3383 kW, that is, they are very similar, but the calculated energy is what is needed per unit of time, and that the dehydration is done in less time, as experienced by (Alvarado, 2017, p. 33) that uses a time of 45 minutes in dehydration, and what is reported in the manual of (PRODAO, 2020, p. 20-24) that they perform it at a time of 20 hours, 1200 minutes, that is, it would require more than ten times the amount of energy of the lyophilizer compared to the use of the dehydrator.

Strawberry

The energy rating calculated in the dehydration of the strawberry was 0.3383 and 0.05305 kW in the lyophilization, which denotes a difference between the two processes, if it is minimal, but by needing this energy for a unit of time, less energy is needed to dehydrate the bur, with respect to the time of lyophilizing the strawberry.

4.4.1 Economic balance sheet

		Apple		Strawberry	
Raw material	**Quantity grams**	Dehydrated	Lyophilized	Dehydrated	Lyophilized
Fruits	250	0,38	0,38	0,25	0,25
Containers		0,08	0,08	0,08	0,08

Energy		0,06	0,58	0,10	0,29
Total, expenditures		0,51	1,038	0,43	0,62
Quantity obtained, g		34,71	34,71	34,71	34,71
Production costs, dollar/g		0,51	1,04	0,43	0,62
Selling price per g		0,017	0,017	0,017	0,017
Total, income		0,59	0,59	0,59	0,59
Benefit/cost		1,15	0,57	1,38	0,95

Table 6. Economic analysis of dehydration and freeze-drying of apples and strawberries
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Apple

According to the benefit/cost indicator, it was determined that for every dollar invested in the dehydrated apple, 15 ctvs is earned, in the case of the lyophilization of the apple, 43 ctvs are lost per dollar invested, these values are related to (Rappi, 2022) which says that for each gram of dehydrated and freeze-dried fruit they can be sold at a price of 0.017 ctvs., Therefore, it is determined that the dehydration process represents a greater gain compared to the lyophilization process in which, instead of there being a gain, economic losses are evident.

Strawberry

It was determined that when using the dehydration process in the strawberry you have a gain of 38 ctvs. for each dollar, and with the present lyophilized you have losses of 5 ctvs. for each dollar invested, loss that is due to the fact that the lyophilization process lasts up to 10 times longer than the lyophilized, and energy (kW) represents an expense in food processes according to the time it lasts.

5. Conclusions

- The dehydration process of strawberry and apple (4.26h) requires a shorter time than the lyophilization process (37.83h), a yield of 13.88% in dehydration compared to 12.36% with lyophilization.

- As for the sensory characteristics, both the strawberry and the apple received a rating of likes moderately, and, on the other hand, the microbiological analysis reported absence of microorganisms, which is why it is considered suitable for consumption.

- In the mass and energy balance, less weight loss was established when the dehydrator was used, reaching a more efficient energy consumption when the dehydration method was used.

➢ When using the dehydration process in the apple and the strawberry there is a greater gain (15 and 38 ctvs.) respectively, compared to the lyophilization process, in which losses were obtained, therefore, it follows that when using the dehydrator a greater profitability is obtained.

6. Recommendations

➢ Use the dehydration method in both apple and strawberry, because it requires less time, energy and achieves a higher profitability.

➢ Continue with the work of fruit dehydration, handling more process variables, all in order to establish a broader scientific basis in this research field.

➢ Promote the consumption of dehydrated fruits, because they have similar characteristics to fresh fruits, offering longer shelf life, ease of transport and reduced storage space.

References

ADRIÁN BELTRÁN, Kevin Fabian. Elaboration of biscuits from dehydrated apple (malus domestica) and linseed (linium usitatissimum l) as a source of natural antioxidant [Online] (Titling project). (Engineering) Universidad Agraria del Ecuador, Guayaquil, Ecuador. 2020. pp. 51- 59. [Accessed: 2022-06-26]. Available in: https://cia.uagraria.edu.ec/Archivos/ADRIAN%20BELTRAN%20KEVIN%20FABIAN.pdf

ALVARADO, M. "Study of the stramberry drying process using microwave dryer". Journal of Prospectiva [online], 2017, (Colombia) 15(29), pp. 29-34. [Accessed: 20 August 2022]. ISSN 1090-7807. Available in: 10.15665/rp.v15i1.658

AMORES VIZUETE, Daniela de los Ángeles. Nutritional and nutraceutical evaluation of dehydrated blackberry (rubus glaucus) by the lyophilization method and comparison with that obtained by dehydration in microwaves and tray dryers [Online] (Titling work). (Biochemistry). Polytechnic School of Chimborazo, Ecuador. 2011. pp. 74- 75. [Accessed: 2022-07-23]. Available in: http://dspace.espoch.edu.ec/bitstream/123456789/1989/1/56T00297.pdf

AYALA NARANJO, Nancy Sofía, & CALLE ROMERO, Adriana Karolina. Application of dehydration, maceration and blanching techniques for the conservation of Red Delicious, Flor de Mayo and Emilia apples. [In linea] (Degree work). (Bachelor's degree). University of Cuenca, Cuenca, Ecuador. 2016. pp. 18-28. [Accessed: 2022-03-19]. Available in: http://repositorio.puce.edu.ec/bitstream/handle/22000/10657/Tesis%20Aclalau%20Alimentos%20S.A.%20Juan%20Burbano.pdf?sequence=1

BURBANO TORRES, Juan Francisco. Improvement of the production and sales processes of a small company in the fruit dehydration industry "case: Aclalau Alimentos S.A.". [In linea] (Degree work). (Mastered). Pontificia Universidad Católica del Ecuador - Matriz, Quito, Ecuador. 2015. pp. 11-12. [Accessed: 2022-03-19]. Available in: http://repositorio.puce.edu.ec/bitstream/handle/22000/10657/Tesis%20Aclalau%20Alimentos%20S.A.%20Juan%20Burbano.pdf?sequence=1

CABASCANGO, O. Dehydration Manual [online]. Ecuador: Publication of the Technical University of the North, 218. [Accessed: 14 June 2022]. Available in: https://www.ppd-ecuador.org/wp-content/uploads/2019/FondoBecas/SierraNorte/UTN-Omar-Uso-Deshidratador-solar-vf.pdf

CARPIO DIAZ, Luis Fernando. Design of a pilot freeze dryer for the study of dehydration processes and conservation of agro-industrial products through vacuum drying. [In linea] (Degree work). (Bachelor's degree). Universidad Mayor de San Andres, La Paz, Bolivia. 2018. pp. 7-8. [Accessed: 2022-03-19]. Available in: https://repositorio.umsa.bo/bitstream/handle/123456789/18231/PG-2043.pdf?sequence=1&isAllowed=y

CARRILLO INUNGARAY, M.; & FUENTES PRADO, E.; & GIJÓN ARREORTÚA, I.; & PEREZ, R." Application of lyophilization in the preservation of Microemulsions used in functional foods and nutraceuticals: a case of food engineering". TLATEMOANI Revista Académica de Investigación [online], 2018, (Spain) 2(29), pp. 295-298. [Accessed: 16 June 2022]. ISSN 19899300. Available in: https://dialnet.unirioja.es/descarga/articulo/7337190.pdf

CASTAÑO RODRÍGUEZ, Jhersson Dulvier, **& LONDOÑO QUINTERO, Francisco Javier.** Design and simulation of a strawberry dehydration system with alternative energies [Online] (Titling work). (Master's degree) Nueva Granada Military University, Bogota, Colombia. 2017. pp. 113- 114. [Accessed: 2022-07-23]. Available in: https://repository.unimilitar.edu.co/bitstream/handle/10654/16725/Casta%C3%B1oJherssonFranciscoLondo%C3%B1o2017.pdf?sequence=1

CAYAMBE CAYAMBE, Nancy Elizabeth. Diagnosis of the Agroproductive chain of strawberry (Fragaria Ananassa) in three Provinces of La Sierra - Centro Zona 3 [Online] (Titling work). (Engineering) Polytechnic School of Chimborazo, Riobamba, Ecuador. 2018. pp. 105-110. [Accessed: 2022-06-13]. Available in: http://dspace.espoch.edu.ec/bitstream/123456789/10403/1/27T0404.pdf

CEBALLOS PEÑALOZA, Adela. Comparative study of three drying systems for the production of a dehydrated fruit powder [Online] (Degree project). (Engineering) National University of Colombia, Manizales, Colombia. 2008. pp. 58- 62. [Accessed: 2022-06-20]. Available in:

https://repositorio.unal.edu.co/bitstream/handle/unal/2687/adelamariaceballospenaloza.2008.pdf?sequence=1&isAllowed=y

DÁVILA CANO, María Andrea. Preparation of powdered flavorings, from five dehydrated fruits such as: fig, quince, medlar, mortiño, and uvilla for application in five types of biscuits and five types of cookies. [In linea] (Degree work). (Bachelor's degree). University of Cuenca, Cuenca, Ecuador. 2015. pp. 19-21. [Accessed: 2022-03-19]. Available in: https://dspace.ucuenca.edu.ec/bitstream/123456789/22376/1/Trabajo%20de%20titulaci%C3%B3n.pdf

DORAN, P. *Engineering principles of bioprocesses*. [Online]. London-England: Acribia, Editorial, S.A, 2015. [Accessed: 23 October 2022]. Available in: https://books.google.com.ec/books/about/Principios_de_ingenier%C3%ADa_de_los_bioproc.html?id=oQS-OwAACAAJ&redir_esc=y

ELECTRIC COMPANY QUITO. Rates of the electricity company quito, among the lowest in the region [blog]. Quito: July 19, 2022. [Accessed: 12 October]. Available at: http://www.eeq.com.ec:8080/zh_TW/nosotros/comunicamos/noticias/-/asset_publisher/PDd0RO7lSu5d/content/tarifas-de-la-empresa-electrica-quito-entre-las-mas-bajas-de-la region/pop_up;jsessionid=DB1D933032CC4ADB8CD0C6D87EB68431?controlPanelCategory=portlet_101_INSTANCE_PDd0RO7lSu5d&redirect=http%3A%2F%2Fwww.eeq.com.ec%3A8080%2Fzh_TW%2Fnosotros%2Fcomunicamos%2Fnoticias%3Bjsessionid%3DDB1D933032CC4ADB8CD0C6D87EB68431%3Fp_p_id%3D101_INSTANCE_PDd0RO7lSu5d%26p_p_lifecycle%3D0%26p_p_state%3Dpop_up%26p_p_mode%3Dview%26controlPanelCategory%3Dportlet_101_INSTANCE_PDd0RO7lSu5d%26_101_INSTANCE_PDd0RO7lSu5d_advancedSearch%3Dfalse%26_101_INSTANCE_PDd0RO7lSu5d_keywords%3D%26_101_INSTANCE_PDd0RO7lSu5d_delta%3D%26p_r_p_564233524_resetCur%3Dfalse%26_101_INSTANCE_ PDd0RO7lSu5d_controlPanelCategory%3Dportlet_101_INSTANCE_PDd0RO7lSu5d%26_101_INSTANCE_PDd0RO7lSu5d_andOperator%3Dtrue#:~:text=La%20ARCERNNR%2C%20mediante%20resoluci%C3%B3n%20ARCERNNR,servicio%20de%20energ%C3%ADa%3B%20es%20decir%2C

ERDOCIAIN PÉREZ, Elena. Development of apple snacks under different process conditions [Online] (Titling project). (Engineering) Escuela Técnica Superior de Ingeniería Agronómica Y Biociencias, Navarra, Spain. 2020. pp. 18- 41. [Accessed: 2022-06-26]. Available in: https://academica-e.unavarra.es/bitstream/handle/2454/37950/TFG%20-%20Elena%20Erdociain.pdf?sequence=1&isAllowed=y

ESPINOZA MANFUGAS, Julia. Food Sensory Assessment [online]. Ciudad de la Habana- Cuba: Editorial Universitaria, 2007. [Accessed: 21 June 2022]. Available in: https://s47003acac0f1f7a3.jimcontent.com/download/version/1463707242/module/8586131883/name/LIBRO%20ANALISIS%20SENSORIAL-1%20MANFUGAS.pdf

GRAJALES AGUDELO, Lina M; &, CARDONA PERDOMO, William; & ORREGO ALZATE, Carlos. "Lyophilization of carom (Averrhoa carambola L.) osmodeshidrated". Revista Cintifica y tecnológica Universidad del Valle, nº 2514 (2005), (Colombia) pp. 1-8.
HINOJOSA, Roberto Francisco. Design of a prototype of a hybrid fruit dehydrator for the Andean region (Degree work) (master's degree). [Online] Polytechnic School of Chimborazo, Faculty of Mechanics. (Riobamba-Ecuador). 2020. pp 50 – 52 [Accessed: 23 October 2022]. Available in: http://dspace.espoch.edu.ec/bitstream/123456789/14091/1/20T01329.pdf

HUARACA AGUAY, Adriana del Pilar. Nutritional and nutraceutical evaluation of dehydrated strawberry (*Fragaria vesca*) by the lyophilization method and comparison with that obtained by microwave dehydration [Online] (Titling project). (Biochemical) Polytechnic School of Chimborazo, Riobamba, Ecuador. 2011. pp. 101- 111. [Accessed: 2022-06-20]. Available in: http://dspace.espoch.edu.ec/bitstream/123456789/1994/1/56T00302.pdf

LONDOÑO GARCÍA, Rodrigo. Mass and energy balances. [blog]. [Accessed: 19 March 2022]. Available in: https://blog.utp.edu.co/balances/files/2015/02/LIBRO-BME2015-1.pdf

LÓPEZ SAMPEDRO, Sandra Elizabeth, & LEÓN NARANJO, Ana Cristina, & BAÑO AYALA, Darío Javier, & ARBOLEDA ALVAREZ, **Luis Fernando**. "Determination of a predictive drying model for the apple produced in the central sierra". Digital Awareness [online], 2021, (Ecuador) 4(2), pp. 247-260. [Accessed: 23 August 2022]. ISSN: 2600-5859. Available in: https://doi.org/10.33262/concienciadigital.v4i2.1663

MICHELIS, Antonio,; OHACO, Elizabeth. Dehydration and drying of fruits, vegetables and mushrooms [online]. Argentina: Comunicación Téncia Nº 84 Área Desarrollo Rural, 2014. [Accessed: 23 June 2022]. Available in: https://inta.gob.ar/sites/default/files/script-tmp-inta_cartilla_secado.pdf

MORENO-GUARÕN, Diana, & SIERRA-HOYOSI, Hernán, & DIAZ-MORENO, Consuelo. "Color and texture, characteristics associated with the quality of dehydrated tomato". Vitae [online], 2012, (Colombia) 19 (1), pp S201-S203. [Accessed: 26 September]. ISSN 0121-4004. Available in: https://www.redalyc.org/pdf/1698/169823914058.pdf

NTE INEN 2996 2015. *Dehydrated products. Carrot, pumpkin, uvilla. Requirements*
NTE INEN 2996 2015-XX Dehydrated products. Carrot, pumpkin, uvilla. Requirements

OCAÑA JARA, Eder Renato. Obtaining freeze-dried grapes [online] (titling work). (Chemical in Food) Central University of Ecuador, Quito, Ecuador. 2013. pp. 1- 5. [Accessed: 2022-06-13]. Available in: http://www.dspace.uce.edu.ec/bitstream/25000/1401/1/T-UCE-0008-%2006.pdf

PARZANENCE, Magali. *Lyophilization of food* [Technical Sheet]. Buenos Aires, Argentina: Alimentos Argentinos. [Accessed: 14 June 2022]. Available in: http://www.alimentosargentinos.gob.ar/contenido/sectores/tecnologia/Ficha_03_Liofilizados.pdf

PARZANESE, Magali. Freeze-drying of food. [blog]. [Accessed: 19 March 2022]. Available in: http://www.alimentosargentinos.gob.ar/contenido/sectores/tecnologia/Ficha_03_Liofilizados.pdf

PATERNINA, Maribel García,; BERMUDEZ, Armando Alvis,; GARCIA MOGOLLON, Carlos. "Evaluation of Osmotic and Microwave Dehydration Pretreatments in Obtaining Mango Flakes (Tommy Atkins)". Research Group Processes and Agroindustry of Vegetables [online], 2015, (Colombia) 26(5) pp. 63-70. [Accessed: 23 June 2022]. doi: 10.4067/S0718-07642015000500009. Available in: https://scielo.conicyt.cl/pdf/infotec/v26n5/art09.pdf

PRODAO. Alternatives for the Application of the Freeze-Drying Process in Fruits and Vegetables compatible with the Organic Regulations [Online] Ministry of Agriculture, Livestock and Fisheries, Argentina. 2020. [Accessed: August 26, 2022]. Available in: https://alimentosargentinos.magyp.gob.ar/contenido/valorAr/organicos/proyecto/archivos/Liofilizacion_frutas_hortalizas.pdf

QUILUMBAQUIN GUACHAMIN, Yajaira Lizeth. Osmodehydration as an alternative for the improvement of the sensory characteristics of the strawberry (Fragaria vesca; variety Albion) conventionally dehydrated [Online] (Titling project). (Engineering) State Polytechnic University of Carchi, Tulcán, Ecuador. 2020. pp. 43- 51. [Accessed: 2022-06-27]. Available in: http://repositorio.upec.edu.ec/bitstream/123456789/880/1/012%20Osmodeshidratacion%C3%B3n%20como%20alternativa%20para%20el%20mejoramiento%20de%20la%20caracter%C3%ADsticas%20sensoriales%20de%20la%20fresa.pdf

RAMÍREZ NAVAS, Juan. "Freeze-drying of food". ReCiTeIA Magazine. No. 6. (2007) pp. 1-39.

RAPPI. Frutas Supermaxi [blog]. Ecuador: August 23, 2022. [Accessed: 29 October]. Available in: https://www.rappi.com.ec/tiendas/13189-supermaxi-market/frutas-y-verduras/frutas

REYES, Camilo Andrés Viability of arazá (Eugenia stipitata) as a source of compounds beneficial to health, effect of different processing methods on its nutritional quality [Online] (Titling work). (Doctorate) National University of La Plata, Buenos Aires, Argentina. 2020. pp. 28- 30. [Accessed: 2022-06-13]. Available in:

http://sedici.unlp.edu.ar/bitstream/handle/10915/94884/Documento_completo.pdf-PDFA.pdf?sequence=1&isAllowed=y

SEPÚLVEDA, Marcela,; QUITRAL, Vilma,; SCHWARTZ, Marco,; VIO, Fernando,; ZECHARIAH, Elizabeth,; WERTHER, Kern. "Healthy properties and sensory quality of apple snacks intended for school feeding". SLAN, Vol. 61 No. 4 (2011), (Uruguay) pp. 423-428.
LATIN AMERICAN SOCIETY FOR QUALITY. "Cost / Benefit Analysis" [blog]. [Accessed: 19 March 2022]. Available in: http://sigc.uqroo.mx/Manuales/Institucional/Procedimientos/Secretaria%20General/Gestion%20Calidad/DGC-001/Metodologias/Costob.pdf

TAMBA SANDOVAL, Juan Enrique. Identification of the main pests that affect the cultivation of strawberry (Fragaria vesca) in three agro-ecological zones of the Quito canton, Province of Pichincha. [In linea] (Degree work). (Engineering). State University of Bolivar, Guaranda, Ecuador. 2015. Pp. 1-6. [Accessed: 2022-03-19]. Available in: https://dspace.ueb.edu.ec/bitstream/123456789/1280/1/171.pdf

TERAN SULLCA, Helbert Cristian. Evaluation of the lipid oxidation of a sauce based on spinach (spinacia oleracea), basil (ocimum basilicum), using two types of vegetable oils: soybean (glycine max) and olive oil (olea europea) [Online] (Titling project). (Engineering) Universidad Nacional de San Agustín de Arequipa, Arequipa, Peru. 2019. pp. 60- 98. [Accessed: 2022-06-21]. Available in: http://repositorio.unsa.edu.pe/bitstream/handle/20.500.12773/11412/IAtesuhc.pdf?sequence=1&isAllowed=y

VITERI MIRANDA, Patricia Alexandra Blackberry pulp stability study [Online] (Titling work). (Engineering). Escuela Superior Politécnica de Litoral, Faculty of Engineering in Mechanics and Production Sciences, Guayaquil. 2012. pp. 57. [Accessed: 2022-78-23]. Available in: https://www.dspace.espol.edu.ec/bitstream/123456789/13705/1/D-43086.pdf