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Use and conservation of by-products from the grape processing industry for food purposes

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ABSTRACT

Brazil is one of the world's largest producers of fruit waste, primarily originating from the food processing industries, which can lead to environmental problems. Consequently, numerous studies have been conducted to investigate the nutritional and functional value of fruit residues, suggesting alternative uses. Grapes are a great source of antioxidant compounds; a large amount of waste is generated during their industrial processing for wine, juice, jelly, etc. Such residues may contain substantial amounts of antioxidant compounds that arouse scientific interest due to potential health benefits. This study aimed to evaluate the possibility of reusing grape pomace to avoid improper disposal by comparing oven-drying and freeze-drying techniques to determine which process yields better results. Different temperatures and drying methods were tested (oven: 45, 65, 85, and 105°C; and freeze-drying). The residues and flours (grape pomace flours) were analyzed for their physical, chemical, nutritional, and functional properties. The results show that grape pomace contains compounds and characteristics that could be valuable in food production as a source of sugars, anthocyanins, and proteins. The characterization of the flours revealed that regardless of the drying technique, all flours exhibited quality for their utilization. Moreover, after drying at 85°C, most bioactive compounds are generally degraded, whereas the freeze-drying process and low-temperature drying better preserve the flour's characteristics. In summary, grape pomace can be utilized in food production, enhancing the physical, chemical, nutritional, and functional properties of products made using its flour.

Keywords: Antioxidants. Centesimal composition. *Vitis*. Drying. Grape pomace.

1 INTRODUCTION

The agro-industries of plant products, such as fruits, generate a large amount of waste during their processing. Depending on the processed fruit, the residues can contain significant amounts of antioxidant compounds (BARCELLOS et al., 2018). In addition to the environmental damage and impacts of improper disposal, these residues can cause an economic deficit in the production chain, as they can be a source of nutritional compounds such as fibers, vitamins, and antioxidants, which can combat hunger and issues caused by free radicals (LAVELLI et al., 2016).

The primary residue from the industrial processing of grapes is called grape pomace (comprising pulp remnants, skins, and seeds), which accounts for 20% of the fruit's weight (MANESSIS et al., 2020). Compounds present in grapes, such as resveratrol, linoleic acid, palmitic acid, phenolic compounds, and fiber residues, remain in the grape pomace in varying amounts depending on the extraction process used. Currently, a significant portion of the grape pomace produced by wineries is discarded as waste (BERES et al., 2017). Grape pomace flour is produced through drying processes of the pomace and can be used as a supplement to wheat flour in the preparation of various products. Grapes, as well as grape pomace flour, have high levels of fiber and significant amounts of antioxidants (BENDER et al., 2016).

Oven drying is a heat transfer process; it is generally recommended that the drying of vegetables be carried out at temperatures below 70°C to avoid sugar caramelization and the formation of undesirable compounds (DE ABREU, 2001). On the other hand, freeze-drying is also a drying method used for vegetables, which employs vacuum and low temperatures in the process, allowing for better preservation of quality characteristics (VIEIRA et al., 2012).

This study aimed to evaluate the possibility of reusing grape pomace to avoid improper disposal by comparing oven-drying and freeze-drying techniques to determine which process yields better results.

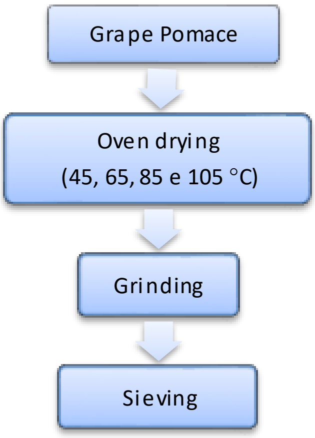
2 MATERIAL AND METHODS

Grape pomace from non-vinifera species, donated by a fruit jelly industry, was used. Grape pomace flours were produced through oven drying or freeze drying.

2.1 Oven drying

Grape pomace was dried in a hot air circulation oven at different drying temperatures (45, 65, 85, and 105°C for 3 days). At the end of the drying process, the dried grape pomace was ground and sieved. The final product, called grape pomace flour, had its production process exemplified in the following flowchart (Figure 1).

Figure 1. Flowchart of the production of grape pomace flour after the hot air circulation oven drying process.

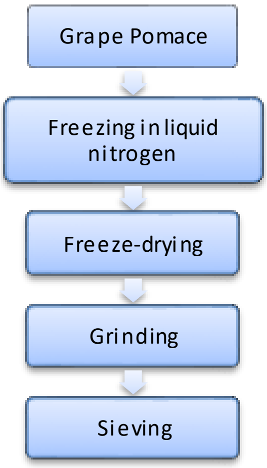


Source: Prepared by the authors (2024).

2.3 Freeze-drying

For the freeze-drying process, grape pomace was ground and frozen in liquid nitrogen (-200°C). Subsequently, it was subjected to a vacuum (internal pressure of approximately 100 µmHg) for 4 days to remove water by sublimation using a freeze-dryer (brand: Martin Christ Gefriertrocknungsanlagen, model: Alpha 1-2 Ldplus). Production of these flours is presented in the following flowchart (Figure 2).

Figure 2. Flowchart of the production of grape pomace flour after the freeze-drying process.



Source: Prepared by the authors (2024).

2.4 Laboratory analyses

Both the grape pomace and the produced flours were evaluated for physical characteristics, including hygroscopicity, solubility (LABORATORY GNR, 2010), water retention, and oil retention (WANG and KINSELLA, 1976, adapted by CASTILHO et al., 2010). Additionally, chemical characteristics were assessed: pH, total acidity, reducing sugars, and total soluble sugars (IAL, 2008); proximate composition and energy analysis (IAL, 2008). Some bioactive compounds were also evaluated using spectrophotometric methods: vitamin C (IAL, 2008), pigments - anthocyanins, chlorophyll, and carotenoids (SIMS and GAMON, 2002), total phenols (SINGLETON and ROSSI, 1965), and total flavonoids (AWAD et al., 2000).

2.5 Experimental design, statistical analysis, and presentation of results

Experimental design was completely randomized with 4 treatments (oven drying at 45°C, 65°C, 85°C, 105°C, and freeze-drying) and 4 replicates. The results of laboratory evaluations conducted on the grape pomace flours were analyzed by analysis of variance (ANOVA), compared using Tukey's test ($p \leq 0.05$), and presented in tables.

3 RESULTS AND DISCUSSION

3.1 Grape Pomace

Results of the evaluations on the grape pomace are presented in Table 1. Hygroscopicity of dehydrated foods is linked to their physical, chemical, and microbiological stability. The levels of hygroscopicity found were 1.25%, a lower value than that reported by Oliveira et al. (2014) in freeze-dried cajá pomace flour (12.93%). Solubility content found in this research was lower (0.30%) than that reported by Oliveira et al. (2014), who obtained a solubility of around 10% in corn flour.

The pH of the grape pomace was 4.5. In fresh grapes, the pH ranges between 3.5 and 4.5, contributing to the sensory characteristics and color of wines and juices, along with total acidity and other compounds (RIZZON and GATTO, 1987). Since most of the constituents of the grape pulp remain in the juice after processing, it is expected that the remaining grape pomace will have higher pH levels and a reduced acidity condition as well.

Reducing sugars (RS) and total soluble sugars (TSS) correspond to the levels of glucose, fructose, and sucrose in plant tissues; RS and TSS levels in the grape pomace were 23.45% and 26.33%, respectively. The RS and TSS results were higher than those found in non-vinifera grapes studied by Assis et al. (2011), which were 20.02% and 22.04%. Rizzon and Miele (2002) found RS and TSS levels in wine grapes closer to those in our study, at 23.40% and 25.84%.

Moisture content is commonly used to decide the best storage method and how long the residue can be stored. It can favor the growth of spoilage and pathogenic microorganisms and is also related to the characteristics of these microorganisms, as well as the capacity of food components to bind to water molecules, reducing the amount of free water (DA SILVA et al., 2015). The moisture content of the grape pomace in this study was 8.37%, which is lower than the results found by Oliveira and his team (2016), who determined the moisture content of grape pomace to be close to 60%. It is important to emphasize that the moisture content of grape pomace can vary according to the cultivation conditions of these grapes, cultivar, and the type of processing the material underwent. Grape pomace obtained from jelly industries has a moisture content close to 7.9%, as observed by Ribeiro et al. (2016), a value close to that found in our study.

The ash content found was 7.9%, which is higher than the results reported by Oliveira et al. (2016) in grape pomace (approximately 2%). This content describes the percentage of total minerals in the sample, which relatively increases when dried, as likely happened in this study.

Table 1. Physical, chemical, nutritional, and functional content of grape pomace.

Evaluations	Grape Pomace
Hygroscopicity (%)	1.25
Solubility (%)	0.30
Water Retention (%)	5.44
Oil Retention (%)	4.50
pH	4.5
Total Acidity (g citric acid.100g^{-1})	0.64
Reducing Sugars (g glucose.100g^{-1})	23.45
Total Soluble Sugars (g glucose.100g^{-1})	26.33
Moisture (%)	8.37
Ash (%)	7.90
Proteins (%)	7.87
Lipids (%)	3.22
Carbohydrates (%)	72.63
Energy Value (Kcal.100g^{-1})	351.00
Vitamin C (%)	0.96

Total Phenols (mg.100g^{-1})	53.26
Flavonoids (µg. g^{-1})	1.11
Anthocyanins (mg.100g^{-1})	145.85
Total Chlorophyll (mg.100g^{-1})	3.91
Carotenoids (mg.100g^{-1})	22.72

Source: Research Data. Prepared by the authors (2024).

The protein content found in this study was 7.87%, which is lower compared to the results described by Pineau et al. (2011) in grape skin flour, which was 11.2%. On the other hand, Oliveira et al. (2016) found lower protein levels in grape skins, approximately 5.08%. The lipid content found in the grape pomace we studied was 3.22%, as well as the protein content, which was also lower than that reported in literature (grape pomace lipid content above 7%; OLIVEIRA et al., 2016). The lipid and protein content can vary from one study to another, as these nutrients change according to the species and variety of grape, as well as the cultivation method and growing season.

The carbohydrate concentration in the grape pomace was 72.63%, higher than that found by Pineau et al. (2011) in grape skin flour (20%). The energy value we found (351 Kcal.100g^{-1}) was also higher than that reported by Pineau et al. (2011) in grape skin flour (180 Kcal.100g^{-1}).

The vitamin C content in the pomace was 0.96%, results similar to those found by Duarte et al. (2020).

In a study on grape pulp, skin, and seed residues, Deng et al. (2011) found levels of total phenols, flavonoids, and anthocyanins in pulp residues (8.31; 0.63; 29.82 mg.100g^{-1}, respectively), skin (8.23; 0.63; 29.82 mg.100g^{-1}, respectively), and grape seed (0.11; 0.05 mg.100g^{-1}, with no traces of anthocyanins, respectively). In this work, the results were higher than those described by the authors, especially in the case of grape pomace (phenols, 53.26; flavonoids, 1.11; and anthocyanins, 145.85 mg.100g^{-1}). Such results can be attributed to the fact that the grape pomace analyzed in this research was not separated but used as a whole, as a mixture of residues (pulp remnants, seeds, and skins discarded by the jelly industry). Soares et al. (2008) describe phenol levels close to 80 mg.100g^{-1}, flavonoids at 19 mg.100g^{-1}, and anthocyanins at 186 mg.100g^{-1}, in Isabel grapes

3.2 Grape Pomace Flour

The results of the physical evaluations conducted on the grape pomace flours produced with different drying processes (oven drying at 45°C, 65°C, 85°C, 105°C, and freeze-drying) are presented in Table 2

Table 2. Hygroscopicity (%), Solubility (%), Water Retention (%), Oil Retention (%) in grape pomace flours produced with different drying processes (oven drying at 45°C, 65°C, 85°C, 105°C, and freeze-drying).

Drying Process	Hygroscopicity (%)	Solubility (%)	Water Retention (%)	Oil Retention (%)
45°C	1.24^c	0.16^b	3.88^b	3.91^c
65°C	1.23^c	0.17^b	4.89^a	3.73^d
85°C	1.29^b	0.17^b	5.18^a	4.86^b
105°C	1.37^a	0.15^b	5.55^a	3.52^e
Freeze-drying	1.19^c	0.27^a	4.15^b	5.27^a
C. V. (%)	4.87	53.99	27.32	1.63

Means followed by the same letter in the columns do not differ from each other according to Tukey's test ($p \leq 0.05$).
Source: Research Data. Prepared by the authors (2024).

Hygroscopicity is the ability of certain materials to absorb water. The results obtained in the grape pomace flour showed differences between the treatments (temperatures and drying methods) proportional to the increase in drying temperature. Thus, the highest drying temperature resulted in flour with the greatest capacity to absorb water (105°C = 1.37%), and the freeze-dried flour had the lowest capacity (1.19%). These results are higher than those found by Azeredo (2009), who reported a hygroscopicity content of 0.26% in grape skin flour.

The more soluble a flour is, the greater the possibility of adding this flour to juices, smoothies, and ready-to-eat foods, as higher solubility will allow the flour to dissolve more easily (SILVA et al., 2006). The solubility levels in the grape pomace flour found in this research ranged from 0.15 to 0.27%. It can be observed that the highest solubility content was for the freeze-dried flour, which can be attributed to the fact that the freeze-drying process is more efficient in removing water compared to the oven drying method (AYDOGDU et al., 2018). Similarly, Ribeiro et al. (2016) obtained a solubility of 0.20% in grape flour

Water retention (WR) and oil retention (OR) are technological properties that refer to the amount of dietary fiber present in samples/foods. Foods with high WR are associated with a greater feeling of satiety. Food products with high OR can be used to stabilize foods with high lipid content; moreover, it is related to the fiber's ability to bind to intestinal substances such as cholesterol (CASTRO et al., 2017). In general, the ability to form gels, retain water and oil, and increase viscosity influences the texture of products, the stability of emulsions, and improves the shelf life of products (ELLEUCH et al., 2011). The OR levels observed in this work were influenced by the increase in the temperatures of the drying processes tested. Therefore, the highest drying temperature resulted in flour with the greatest oil absorption capacity (CASTRO et al., 2017). It is noteworthy that in the freeze-drying process, the OR levels were similar to the levels found in flours made with the lowest oven drying temperature

The WR levels were also different among the tested drying temperatures, with a higher WR level observed in the freeze-drying process. This was also observed by Dutra et al. (2012), when drying grape skins at different temperatures (40 and 70°C) in ovens and also using freeze-drying comparatively. Raw materials with higher WR levels can be applied in foods with high water content. The freeze-dried flours showed higher WR levels compared to the flours made using oven drying processes at different temperatures (ELLEUCH et al., 2011).

The levels found in this study for WR and OR are close to those found by Castro et al. (2017) in grape skins, which were 4.8% and 1.7%, respectively.

The results of the chemical evaluations conducted on the grape pomace flours produced with different drying processes (oven drying at 45°C, 65°C, 85°C, 105°C, and freeze-drying) are presented in Table 3.

Table 3. pH, Total Acidity (g citric acid.100g^{-1}), Reducing Sugars (g glucose.100g^{-1}), Total Soluble Sugars (g glucose.100g^{-1}) in grape pomace flours produced with different drying processes (oven drying at 45°C, 65°C, 85°C, 105°C, and freeze-drying).

Drying Process	pH	Total Acidity (g citric acid.100g^{-1})	Reducing Sugars (g glucose.100g^{-1})	Total Soluble Sugars (g glucose.100g^{-1})
45°C	3.1^{a}	0.29^{a}	22.73^{a}	19.81^{b}
65°C	3.1^{a}	0.18^{c}	22.73^{a}	19.23^{c}
85°C	3.1^{a}	0.22^{b}	14.29^{b}	13.51^{d}
105°C	3.0^{a}	0.22^{b}	11.11^{c}	10.00^{e}
Freeze-drying	2.9^{b}	0.16^{c}	22.73^{a}	25.00^{a}
C. V. (%)	2.24	0.21	18.71	0.91

Means followed by the same letter in the columns do not differ from each other according to Tukey's test ($p \leq 0.05$).
Source: Research Data. Prepared by the authors (2024).

The pH in the oven-dried flours ranged from 3.0 to 3.1, regardless of the drying temperature. Freeze-drying, however, produced flour with a lower pH of 2.9. Acidity was higher in oven drying at the lowest temperature and lower in freeze-drying (ranging from 0.18 to 0.29 g citric acid.100g^{-1}). Foods considered acidic have pHs below 4, making them less susceptible to the action of microorganisms (AZEREDO, 2009). Total acidity content of a food is related to the presence of organic acid and, in the case of grapes, the most significant levels of acids are in the skin. The acidity results of this research are consistent with those found by Dalbó et al. (2015) in grape skins (0.23 g citric acid.100g^{-1}) and grape pulp (0.10 g citric acid.100g^{-1}).

Reducing sugars (RS) and total soluble sugars (TSS) decreased in the treatments as the drying temperature was increased. Thus, higher drying temperatures may be related to the degradation of sugars in the grape pomace flour studied. In the grape pomace flour dried in an oven at 45°C and 65°C and freeze-dried, the sugar levels were similar: reducing sugars: 22.73 g.100g^{-1}, and total soluble sugars: 19.81, 19.23, and 25.00 g.100g^{-1}, respectively. With the increase in temperature from 85°C, a reduction in sugar levels is observed, suggesting the degradation of these molecules (RS and TSS) at higher temperatures (DUARTE et al., 2020). The freeze-drying process for grape pomace resulted in higher RS and TSS contents, which may indicate that this drying method is more suitable for preserving the sugar content in grape pomace flours.

The results of the nutritional evaluations conducted on the grape pomace flour made with different drying processes (oven drying at 45°C, 65°C, 85°C, 105°C, and freeze-drying) are presented in Table 4.

Table 4. Moisture (%), Ash (%),Proteins (%),Lipids (%), Carbohydrates (%) and Energy Value (Kcal.100g^{-1}) in grape pomace flours produced with different drying processes (oven drying at 45°C, 65°C, 85°C, 105°C, and freeze-drying).

Drying Process	Moisture (%)	Ash (%)	Proteins (%)	Lipids (%)	Carbohydrates (%)	Energy Value (Kcal.100 g^{-1})
45°C	4.71^{a}	2.22^{b}	3.02^{b}	3.26^{a}	86.66^{c}	373.93^{a}
65°C	2.30^{c}	2.30^{b}	2.69^{c}	2.80^{a}	89.92^{b}	383.03^{a}
85°C	2.66^{b}	2.66^{a}	2.72^{c}	3.14^{a}	88.91^{b}	380.29^{a}
105°C	2.06^{c}	2.06^{b}	2.30^{d}	1.32^{b}	92.29^{a}	384.18^{a}
Freeze-drying	0.50^{d}	1.95^{b}	4.88^{a}	1.24^{b}	91.24^{a}	390.85^{a}
C. V. (%)	14.49	16.02	9.61	20.43	0.88	3.02

Means followed by the same letter in the columns do not differ from each other according to Tukey's test ($p \leq 0.05$).
Source: Research Data. Prepared by the authors (2024).

The moisture contents of the flours were highest in the samples oven-dried at 45°C (4.71%); at other oven-drying temperatures, they ranged from 2.06 to 2.66%. The freeze-dried grape pomace flour had the lowest moisture content (0.5%). It is important to note that all the flours are produced to meet the standards required by ANVISA RDC 263/2005 (BRASIL, 2005), which sets a maximum moisture content of 15% for fruit and seed flours (SORIA and CONTE, 2000). Low moisture and low pH reduce the risk of enzymatic and non-enzymatic reactions and microbiological contamination (LAVELLI et al., 2016). Thus, grape pomace flours, regardless of the drying process, are considered safe foods with chemical, biochemical, and microbiological stability based on the evaluated parameters (FERREIRA, 2010).

The grape pomace flours had ash content (ranging from 1.95 to 2.66%) relatively similar across all drying temperatures. According to Gondim et al. (2005), the highest mineral concentrations are found in grape skins and seeds.

The protein content differed among the tested drying temperatures. Lower temperature drying processes (freeze-drying, drying at 45°C) resulted in higher protein content, with the best results for freeze-drying. It is likely that proteins in the grape pomace were degraded with the increase in drying process temperature. We observed lower protein concentrations at higher drying temperatures (65, 85, and 105°C). Sousa et al. (2014), researching grape residue flour subjected to an oven-drying process at 80°C, found a protein content of around 2.80%, a result similar to those obtained in this study

The low lipid content observed (ranging from 1.24 to 3.26%) can be explained by the use of only grape skins to obtain the flour. The highest lipid content is found in grape seeds (from 10% to 16%) depending on the variety (FERREIRA, 2010).

There was a variation in carbohydrate content among the different drying process temperatures, with the highest carbohydrate content observed in the freeze-dried flour, similar to the results for reducing sugars (RS) and total soluble sugars (TSS)

The results of the functional evaluations (Vitamin C, Total Phenols, and Flavonoids) conducted on the grape pomace flour made with different drying processes (ovens at 45°C, 65°C, 85°C, 105°C, and freeze-drying) are shown in Table 5.

The results of the functional evaluations (Vitamin C, Total Phenols, and Flavonoids) conducted on the grape pomace flour made with different drying processes (ovens at 45°C, 65°C, 85°C, 105°C, and freeze-drying) are shown in Table 5.

The levels of vitamin C found in the grape pomace flours demonstrate that as the drying process temperature increases, there is a decrease in the levels of this vitamin. Vitamin C is a very temperature-sensitive organic molecule. Thus, the freeze-drying process resulted in the highest level of this parameter (0.64%), while the highest oven drying temperature (105°C) resulted in the lowest concentration of vitamin C (0.19%) (AGUDELO MARTÍNEZ et al., 2020).

Table 5. Vitamin C (%),Total Phenols (mg.100g^{-1}), Flavonoids (μg.g^{-1}) in grape pomace flours produced with different drying processes (oven drying at 45°C, 65°C, 85°C, 105°C, and freeze-drying).

Drying Process	**Vitamin C (%)**	**Total Phenols (mg.100 g^{-1})**	**Flavonoids (μg.g^{-1})**
45°C	0.51^{b}	98.06^{c}	1.37^{c}
65°C	0.49^{c}	92.14^{c}	1.59^{c}
85°C	0.45^{d}	112.47^{b}	3.63^{b}
105°C	0.19^{e}	142.24^{a}	5.50^{a}
Freeze-drying	0.64^{a}	109.10^{b}	2.04^{c}
C. V. (%)	0.00	14.23	32.10

Means followed by the same letter in the columns do not differ from each other according to Tukey's test ($p \leq 0.05$).
Source: Research Data. Prepared by the authors (2024).

The phenolic compounds ranged from 92.14 to 142.24 mg.100g^{-1} in the grape pomace flour. The highest levels were found at the highest oven drying temperatures. Studies conducted on grape skins by Soares et al. (2008) describe higher values for total phenolic compounds, 196.378 mg.100g^{-1} in the 'Isabel' cultivar and 183.04 mg.100g^{-1} in the 'Niagara' cultivar. Castro et al. (2017) observed that phenolic compounds and flavonoids in grape pomace from jelly industries are lower compared to grape pomace from wineries. This may occur because grapes used for jelly are subjected to heating during the production process. Additionally, the extraction of phenolic compounds is higher when subjected to higher temperatures. Dutra et al. (2012) evaluated the effect of heat treatment on the concentration of phenolic compounds in tangerine juice and found that as the temperature increased, the concentration of total phenols also increased.

Oliveira et al. (2014), while studying anthocyanins in natural extracts, concluded that the degradation process of phenolics, flavonoids, and anthocyanins is much more related to the effects of light on these compounds than to the effects of temperature.

In the flavonoid content, as well as in phenolic compounds, there was a proportional increase with the increase in drying temperature. At drying temperatures of 45°C, 65°C, and in freeze-drying, 1.37, 1.59, and 2.04 μg.g^{-1} of flavonoids were obtained, respectively. In contrast, drying at 105°C resulted in 5.50 μg.g^{-1} of these compounds. Similar results were described by Dutra et al. (2012), who detected an increase in flavonoid content in grape skins proportional to the increase in drying temperature.

Like phenolic compounds and anthocyanins, carotenoid compounds are part of plant pigments, which can be present in chloroplasts, associated with proteins. Edible plant tissues contain a wide variety of carotenoids, which, in addition to their antioxidant function, can inhibit lipid peroxidation (PANDEY et al., 2016)

The results of the functional evaluations (Carotenoids, Anthocyanins, Total Chlorophyll) conducted on the grape pomace flour made with different drying processes (ovens at 45°C, 65°C, 85°C, 105°C, and freeze-drying) are presented in Table 6.

The carotenoid levels evaluated in this research showed a variation similar to that observed in phenolic compounds and flavonoids. Thus, the increase in drying temperature causes an increase in carotenoid content. At an oven drying temperature of 45°C, 23.19 mg.100g^{-1} of carotenoids was found, while at 105°C, 27.7 mg.100g^{-1} was found. This same trend was observed by Bender et al. (2016), who noted an increase in carotenoids as the temperature increased in the drying process of *Vitis vinifera* L.

Table 6. Carotenoids (mg.100g^{-1}), Anthocyanins (mg.100g^{-1}), Total Chlorophyll (mg.100g^{-1}) in grape pomace flours produced with different drying processes (oven drying at 45°C, 65°C, 85°C, 105°C, and freeze-drying).

Drying Process	Carotenoids (mg.100 g^{-1})	Anthocyanins (mg.100 g^{-1})	Total Chlorophyll (mg.100g^{-1})
45°C	23.19^{b}	123.23^{a}	16.77^{a}
65°C	17.98^{c}	94.51^{b}	17.34^{a}
85°C	21.88^{b}	92.03^{b}	6.72^{c}
105°C	27.20^{a}	92.10^{b}	3.71^{c}
Freeze-drying	21.73^{b}	116.67^{a}	11.26^{b}
C. V. (%)	12.11	11.47	45.40

Means followed by the same letter in the columns do not differ from each other according to Tukey's test ($p \leq 0.05$).
Source: Research Data. Prepared by the authors (2024).

Additionally, Dutra et al. (2012), studying the effect of heat treatment on carotenoid concentration in tangerine juice, reported that at temperatures from 88 to 100°C, carotenoids have different chemical stabilities concerning their degradation. Thus, among the main factors that promote the degradation of carotenoids, we can mention heat, light, enzymatic action, oxidation promoted by lipid oxidation peroxides, etc. (ROCKENBACH et al., 2008)

The anthocyanin content can be affected by cultivation, ripening stage, and storage conditions, among other factors (OLSSON et al., 2004). The anthocyanin content in the samples from this research was higher than those reported by Soares et al. (2008) in non-vinifera grape skins, cv. 'Niagara' and 'Isabel' (70.2 mg.100g^{-1} and 82.15 mg.100g^{-1}, respectively). However, these differences can be explained by the treatments to which the skins were subjected, as well as differences in grape cultivation and production practices

4 CONCLUSIONS

It can be concluded that grape pomace dried at different temperatures in an oven and freeze-dried can be used in food production. The pomace flour produced in this research, when used as an enhancer in foods, can improve the physical, chemical, nutritional, and functional characteristics of these products, as it contains high levels of nutritional and functional compounds.

Considering that the aim of this study was to demonstrate the difference between two drying processes, such as oven drying and freeze-drying, differences were found in most of the evaluated parameters. Depending on the parameter evaluated, the use of freeze-drying, lower temperatures, or higher temperatures in the drying process was more advantageous. However, we know that the freeze-drying process requires a higher cost compared to oven drying techniques (equipment and sample freezing). The grape pomace flours that were dried at lower temperatures in this experiment (45°C and 65°C) can be an alternative for the reuse of these residues

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