

Comparison of Grape Pomace Drying Using a Solar Dryer and Under Open Sun Conditions

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How to cite: Taşeri, L., Gülcü, M., Aktaş, T. (2023). Comparison of Grape Pomace Drying Using a Solar Dryer and Under Open Sun Conditions. *Viticulture Studies (VIS)*, 3(1): 31-40. <https://doi.org/10.52001/vis.2023.18.31.40>

Article History:

Received: 05.01.2023

Accepted: 27.01.2023

First online: 31.01.2023

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Keywords

Grape pomace
open sun drying
solar drying
nutrition content

Abstract

In this research, the effects of open sun drying and solar drying methods on drying characteristics and some quality criteria of grape pomace were investigated for determining an optimum drying method. Fresh grape pomace was provided by Viticulture Research Institute, Grape Juice Processing Plant in Tekirdag, Türkiye. The longest drying period was determined as 147.05 hours for the method of open sun drying while the shortest drying period was determined as 78.5 hours for the method of solar drying. In the solar drier, solar collectors with flat surfaces were used. The drying period was found faster using the solar dryer compared to the use of the open-air drying method. The final moisture content of the solar dried pomace was found to be 11% while the final moisture content of open-air dried pomace was found to be 13.0%. After the drying process, in addition to determining the quality criteria of pomace, seeds and skins were separated using a separator. The content of the total phenolic and antioxidant activity of extracts obtained from open sun-dried grape seeds were determined as 89.57 (g/kg), and 32.89 (μmol troloks/g), respectively whereas the content of the total phenolic and antioxidant activity of extracts obtained from solar dried grape seeds were 112.24 (g/kg), 34.12 (μmol troloks/g), respectively.

Introduction

Grape pomace contains the skins, pulp, seeds, and stems of the fruit. Residues may represent from 17 to 20% of the total volume of grapes depending on the conditions of the harvested grapes and processing conditions.

Depending on the type of pomace components, the cultivar, and climatic and cultivation conditions, grape pomace contains water, proteins, lipids, carbohydrates, vitamins, minerals, and compounds with significant biological properties, such as fiber, vitamin C, and high amounts of phenolic compounds that some of them have antioxidant effects (tannins, phenolic acids, anthocyanins, and resveratrol, catechin, epicatechin, gallic acid, etc.) (Ahn et al., 2002; Jayaprakasha et al., 2003; Amico et al., 2004; Guendez et al., 2005, Sousa et al., 2014; Ma and Zhang, 2017).

Regarding legal, environmental, and economic concerns, grape processing facility owners may view grape pomace as an intriguing and valuable material. Grape pomace has been used for the recovery of food ingredients, nutraceuticals, and functional foods. Particularly grape seeds have a wide range of applications, including edible oil, pharmacological compounds, dietary fiber, important chemicals, antibacterial-related fields, cosmetics, and even the manufacture of biofuel.

Recently, the separation of grape seed from pomace is getting to be more important to obtain some products such as herbal extract, grape seed oil etc. in the World. For this reason, drying of pomace is an important and necessary process for optimum separation of seed. In addition to this, drying of the pomace that has high moisture content prevents the formation of

a suitable environment for microbial activity that can be the reason of degradations due to mold and yeast. Also, the optimum drying process will be effective to obtain high-quality grape pomace products given in Figure 1.

Jordan (2002) stressed that in order to avoid pomace from degrading due to mold growth and to accomplish quick and effective seed separation, pomace should be dried as soon as it is obtained. To achieve optimum storage, particularly for grape seeds, effective drying is also necessary. However, if solar energy is not used for drying pomace, too much energy is necessary for this process. If there is enough solar radiation and enough space that can be protected from rain to spread the pomace for thin layer drying, open sun drying process can be rather cheap and effective. It is suggested that grape seeds should be dried to 8% moisture content to keep the quality and safety of it during storage.

In Tekirdag, Thrace Region in Türkiye, grape pomace is used as mixing of it to soil as fertilizer or used as animal feed. But a large part of this waste is discarded as trash and leads to increase environmental pollution problem like many places in the World. There had been no research performed to evaluate pomace and its fractions especially grape seed by drying and separation of them in this region. For this reason,

in this research it was aimed that drying of grape pomace using two different drying methods namely open sun drying as traditional and energy free method, and solar drying method with collector system. In this way, successful separation of seed and peel from pomace and prevention of microbial spoilage were intended. Some quality analyses such as total phenolic matter, free radical scavenging activity, crude protein, crude fiber, total sugar, microbiological evaluations etc. were performed to determine the effects of drying methods on seed, skin quality and separation success.

Material and Methods

Grape pomace, a by-product of making grape juice from the Kalecik Karası grape variety, was provided for this study by the Viticulture Research Institute in Tekirdag, Türkiye. When the grape was suitable for making juice, it was collected. Grapes were harvested, then they were cleaned, de-stemmed, and shredded. Obtained mash was heated and grape juice was taken using pneumatic membrane press.

Remaining pulp residue namely pomace was used for drying experiments. Stages of obtaining, drying and separation of grape pomace were given in Figure 2.

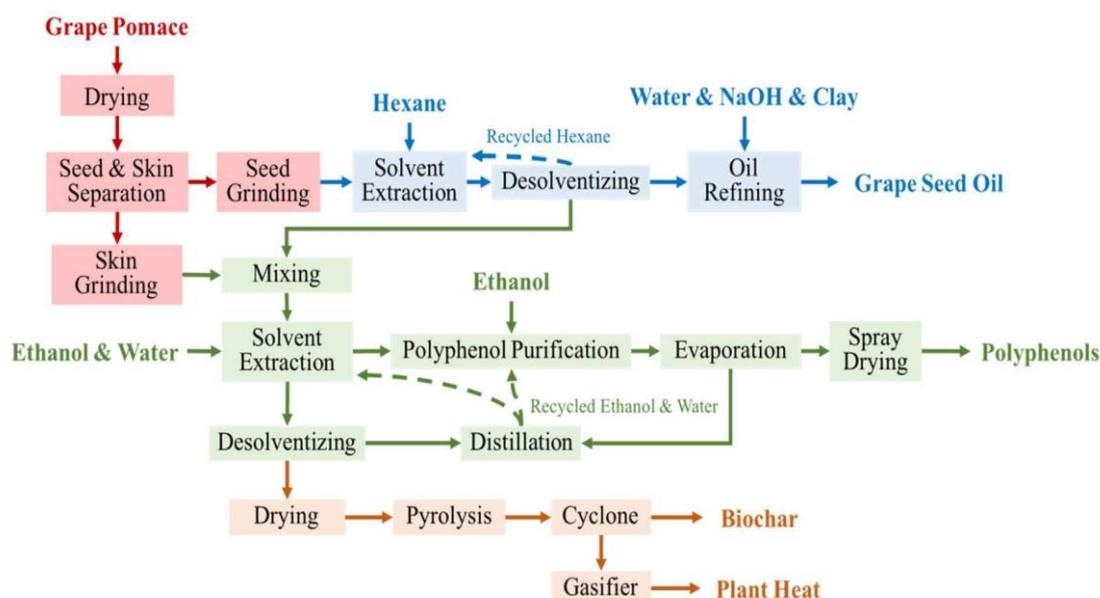


Figure 1. Grape pomace products (Jin, Q. et al., 2021)

Drying experiments were carried out under open sun conditions as traditional drying method and using solar dryer simultaneously. Total length, width and height of solar dryer are 8.1 and 2 m, respectively. In solar dryer, heated air by a solar collector in 5 x 6 m size is sucked and blown into the drying chamber covered plastic material by fan that has 0.37 kW power and 8500 m³h⁻¹ air flow (Alfan brand).

Either open air drying, or solar drying experiments were performed using 4000 g pomace using 60x75 cm perforated drying trays (8.9 kgm⁻²) as three repetitions.

Moisture content values of samples during drying were calculated using following equation:

$$MC = \frac{M_w}{M_d + M_w} \times 100 \quad (1)$$

Where:

MC : Moisture content (% w.b.),

M_d : Dry matter amount of samples (g),

M_w : Water weight of samples (g).

A vibrating type separator that was constructed to separate dried pomace components namely seed and skin was used.

Changes in the following parameters were controlled and determined during and/or end of drying process:

Relative humidity of drying air: Humidity sensors and data logger set were used to monitoring relative humidity value of drying air (Hobo brand) during drying.

Total drying time: Drying time to get the at least 13% moisture content at the end of drying processes performed under different methods was determined by checking the moisture content changes during drying period.

Drying air temperature: Temperature sensors and data logger set were used to monitoring temperature changes of drying air (Hobo brand).

Solar radiation: Solar radiation amount fallen on the solar collectors of dryer was measured periodically using a pyranometer (Apogee brand, MP-100 series) by held it upright to collector from the different points (Wm⁻²).

Drying air velocity: Drying air velocity in solar dryer drying chamber was measured using an anemometer (Lutron brand, AM-4202 model).

Initial moisture content of pomace: Initial moisture content as wet base of pomace was determined using vacuum type oven (Nuve EV 0180).

Water activity value: Changes in water activity values of pomace before and after drying were measured using water activity measurement equipment (Decagon 4 TE brand) according to International AOAC (1995) method.

Yeast and mold amount: Yeast and mold amounts of fresh, open sun dried and solar dried pomace samples were determined. Appropriate dilutions of the sample were waited in Dichloride Rose Bengal Chloramphenicol Agar (DRBC) and petri plates were incubated at 25 °C was about 3-5 days and enumerated (BAM, 1998).

Followed chemical analyses for fresh and dried pomace components namely seed and skin were performed.

Total phenolic matter content (g kg⁻¹): Folin-Ciocalteu method was used to determine total phenolic content as spectrophotometric (Spanos and Wrolstad, 1990). TPC was calculated as grams of gallic acid equivalent per kilogram of dried weight (dw) of sample (g GAE kg⁻¹ dw).

Free radical scavenging activity: Total free radical scavenging activity with a trolox equivalent antioxidant concentration (TEAC) value (µmol troloks/g) was determined according to the elimination of DPPH radicals method explained by Brand-Williams et al. (1995).

Total sugar (%): Total sugar analysis was performed according to the Luff-Schoorl method for mixed samples using homogenizer (IFJU, 1985).

Crude fiber (%): Changed Scharrer method was used to determine crude fiber (TS 4966, 1986).

Crude protein (%): Kjeldahl method was used to determine the crude protein percent of samples (Matissek et al., 1989).

Data analysis: Data were analyzed using PASW 18.0 statistical program. Differences between data were analysed using independent T test with 95% confidence level (P < 0.05).

Results and Discussion

Mean values of meteorological data of Tekirdag City, that has generally high relative

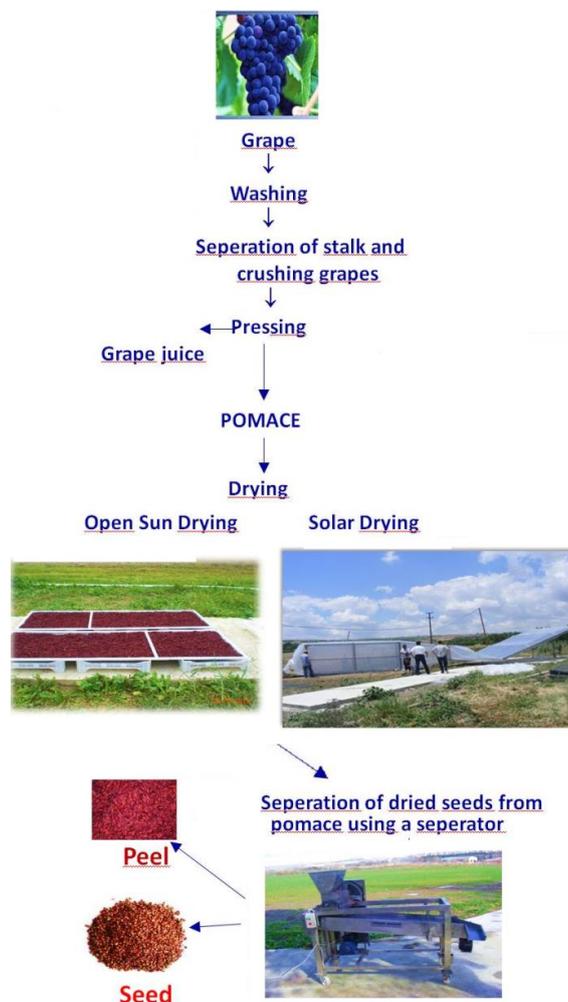


Figure 2. Obtaining, drying of pomace and seperation of grape seed and skin from pomace using a seperator

humidity, were reported as in Table 1 for September as general and for drying period. According to these data, mean values of air temperature, wind velocity, relative humidity and total values of rainfall, and solar radiance time were determined as 22.2 °C, 2.8 ms⁻¹, 73.6%, 8.4 mm and 244 hours, respectively.

Results on drying kinetics of pomace

Changing in moisture content values versus drying time during open sun drying and solar drying of pomace was illustrated in Figure 3.

The moisture content of dried samples decreased to 13% w.b. after 147.05 hours for open-air drying and 78.50 hours for the solar drying process. Minimum moisture content values were determined at 13% for open sun dried samples and 11% for the solar-dried samples.

Results on the water activity, yeast and mold growth

The water activity values of foods and other natural products are effective on the physical, chemical and biological properties more than their moisture content. Water activity of a food is an important factor acting on the loss of its quality by deterioration in microbiological, chemical and biochemical ways (Cemeroglu, 2004).

The bacteria number in food that causes important deterioration problems can not increase if the water activity value of food is under 0.90. Also, mold growth stops completely under a water activity value of 0.65. In addition to these decreasing water activity value stops or restricts the enzymatic changes (Saldamli and Saldamli, 2004).

Measured water activity values for fresh and dried pomace samples were given in Table

Table 1. Meteorological data of Tekirdag City in september during drying process

	17-25 September (Drying period)	September (General)
Mean wind velocity (m/s)	2.34	2.8
Mean relative moisture (%)	75.2	73.6
Total solar radiance time (h)	65.8	244
Global solar radiation (kWh m ⁻²)	265.02	353
Mean air temperature (°C)	20.7	22.2
Total rainfall amount (mm)	7.4	8.4

2. The mean water activity value for the fresh sample was found as 0.82 while it was found as 0.44 for dried samples using the solar dryer. The water activity of samples dried under the sun was found higher compared to those values of solar-dried samples at 0.52. The effect of drying methods on the water activity was found statistically significant ($P < 0.05$).

The yeast and mold number and total bacteria amount of samples that were determined before drying and after drying were given in Table 3.

While the total bacteria number was determined as 39×10^6 CFU/g for the fresh pomace sample, it decreased for both samples that were dried using different drying methods with decreasing moisture content of pomace samples. It was determined as 10.5×10^6 CFU/g for the open sun-dried samples while it was found as 7.1×10^6 CFU/g for solar-dried samples using the solar dryer with the flat surface type collector.

In the same way, mold number was found rather lower also for samples dried using the solar dryer (0.001×10^6 CFU/g) compared to those

values determined for samples dried open sun (0.2×10^6 CFU/g).

Increasing the yeast count determined for the sun-dried samples can be explained by the slow drying rate and more favorable environment for contamination. Also, it can be explained that yeasts have good resistance to low water activity and the sun drying method could not decrease the water activity value for inhibition of the yeasts. The reason for the higher number of total bacteria for open sun-dried samples can be explained by the lower drying rate and higher contamination possibility compared to the solar drying method.

Results on separation success of dried pomace into fractions of seed and skin

Open sun-dried pomace samples with 13% moisture content and solar-dried samples with 11% moisture content were separated into seed and peel fractions using a separator. Separation efficiency was determined as 99% for both samples that were dried using methods of

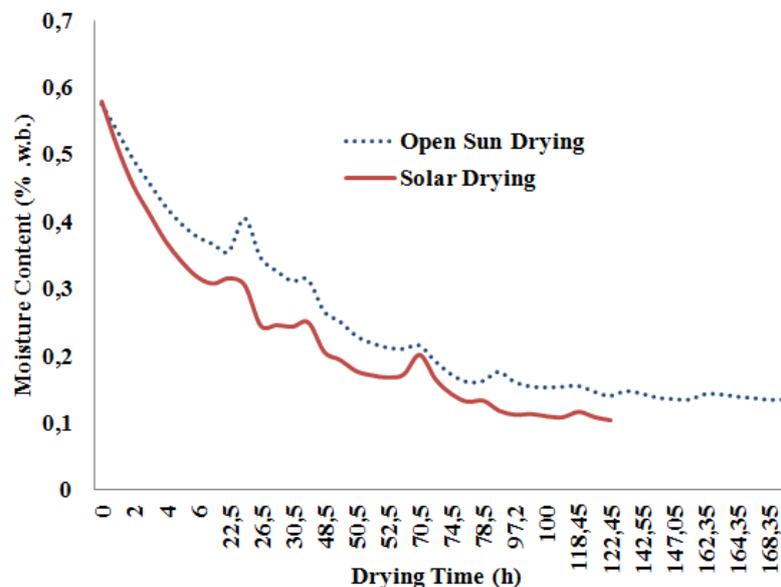
**Figure 3.** Changing of drying kinetics of pomace using different drying methods

Table 2. Changing of water activity values depend on drying methods (Water activity of fresh sample: 0.82)

Drying method	Mean water activity value (a_w)
Open sun drying	0.52
Solar drying using collector system	0.44
($P < 0.05$)	Significant

Table 3. Changing of total bacteria, yeast and mold amount depend on drying methods

Sample	Total bacteria (CFU/g)	Yeast (CFU/g)	Mold (CFU/g)
Fresh	39×10^6	3.4×10^6	0.35×10^6
Open sun dried	$10,5 \times 10^6$	8×10^6	0.2×10^6
Solar dried	7.1×10^6	3×10^6	0.001×10^6

open sun and solar drying. In the separation experiments performed as 3 repetitions, 4000 g dry pomace was separated in every repetition and an average 2009 g skin, 1769 g seed and 222 g other fragments such as dust etc. were obtained.

Results on effects of drying methods on the nutritional value of pomace fractions (seed and skin)

After drying experiments, nutritional properties (total phenolic matter, antioxidant activity, crude protein, crude fiber, total sugar) of components of dried pomace namely seed and skin were determined. These values were compared with values determined for fresh pomace. Results were given as mean values of 3 repetitions of analyses for seed (Table 4) and skin (Table 5).

The total sugar amount of fresh grape seed was determined as 6.36% while it was found as 4.56% for the seed sample separated from open sun-dried pomace and 6.76% for the seed sample separated from solar-dried pomace. The effect of drying methods on total sugar amount

was found statistically significant ($P < 0.05$). However, the effects of drying methods on crude fiber, crude protein, total phenolic content, and antioxidant activity were found statistically insignificant ($P < 0.05$).

Total sugar amount of fresh skin was determined as 41%. The values of crude fiber, crude protein and total sugar of skin samples were determined as 14.82% and 10.86%, 14.16% for open sun-dried skin while these values were found as 12.16%, 9.19% and 30.9% for solar-dried skin (Table 5). Both drying processes decreased the total sugar amount of skin. On the other hand, decreasing in this value was found lower for the solar-dried skin samples compared to the value of open sun-dried skin as seen in Table 5. Effects of drying methods on crude fiber, crude protein and total sugar amount were found statistically significant ($P < 0.05$). Especially results of total sugar amount differences of either seed or skin were found remarkable for samples depending on the drying method. It can be explained that sugar in the medium was used by microorganisms in particular yeast and bacteria due to the longer drying period for open sun drying. On the other hand, effects of

Table 4. Results of chemical analyses of fresh and dried seed samples

Sample	Crude fiber (%)	Crude protein (%)	Total sugar (%)	Total phenolic matter (g/kg)	Antioxidant activity TEAC DPPH ($\mu\text{mol troloks/g}$)
Fresh seed	24.79	10.51	6.36	83.03	26.51
Open sun dried	17.01	8.82	4.56	89.57	32.89
Solar dried	16.49	9.12	6.76	112.24	34.12
($P < 0,05$)	-	-	*	-	-

Results were calculated based on dry matter

*: Differences are significant as statistically

-: Differences are insignificant as statistically

Table 5. Results of chemical analyses of fresh and dried skin samples

Sample	Crude fiber (%)	Crude protein (%)	Total sugar (%)	Total phenolic matter (g/kg)	Antioxidant activity TEAC DPPH ($\mu\text{mol troloks/g}$)
Fresh skin	11.77	6.05	41	16.10	4.06
Open sun dried	14.82	10.9	14.16	27.68	1.89
Solar dried	12.16	9.19	30.9	28.15	2.36
($P < 0,05$)	*	*	*	-	-

Results were calculated based on dry matter

*: Differences are significant as statistically

-: Differences are insignificant as statistically

drying methods on total phenolic matter content and antioxidant activity were found statistically insignificant ($P < 0.05$).

Conclusion

A comparison of open sun drying and solar drying methods for grape pomace in Tekirdağ City of Thrace Region in Türkiye was summarized in Table 6. According to the results, the solar drying method for pomace was primarily suggested in terms of protecting pomace from possible rains, and prevention of microbial degradation due to a faster drying process compared to the open sun drying method. However, infrastructure costs and the necessity of energy usage especially for the fan to force the airflow into the drying cabinet increase the total cost of solar drying process.

Despite the disadvantage related to its cost, the solar dryer was suggested to dry pomace in Tekirdağ City (Türkiye) or other places that have similar climates according to this research results.

Drying of grape pomace in Tekirdağ takes

place between September and October. These times are usually cloudy and extremely rainy. For this reason, there are microbial risks in the open sun drying of grape pulp. In regions with a rainy climate, the pulp must be protected from rain. It can be concluded that a suitable structure should be constructed for drying the pomace in the open sun. Therefore, the efficiency of a processing plant for grape seed or skin depends on the climatic condition of the region similar to the region in this research. For this reason, when the grape pomace processing plant is established, climatic conditions of the selected location should be considered for the drying process. Decisions about the selection of open sun drying process should be made in respect of rains, maximum and minimum temperature values, relative humidity, wind direction and velocity etc. of the region.

NOMENCLATURE

MC	moisture content	%w.b.
M_d	dry matter amount	g
M_w	water amount	g

Table 6. Comparison of drying methods for grape pomace

Factors that affect the quality	Open sun drying	Solar drying
Climatic condition	Risky for drying (rainy, cloudy whether)	Safe for drying
Drying period	Approx. 147.05 hours to 13% moisture content	Approx. 78.50 hours to 13% moisture content
Yeast and mold status	Increasing of yeast values	Decreasing of yeast and mold values
Water activity (a_w should be $< 0,61$)	0.52 (risky)	0.44 (safe)
Sifting status	99% separation for moisture content of 13%	99% separation for moisture content of 13%
Nutritional value of seed	Decreasing in total sugar	No significant change
Nutritional value of skin	Decreasing in total sugar	No significant change
Cost factors	Drying place and protection from rain	Solar collector and energy for fan

Acknowledgements

The authors are grateful for the financial support provided by TAGEM (General Directorate of Agricultural Research and Policies-Türkiye) with a project numbered Tagem/Hsgyad/12/A05/P06/17.

Conflicts of Interest

The authors declare no conflict of interest.

Author Contribution

L.T. and M.G. designed and performed the experiments. T.A. contributed to the interpretation and evaluation of the results. All authors made critical revisions for the intellectual content of the article.

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