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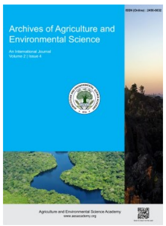

ORIGINAL RESEARCH ARTICLE

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Effect of different processing methods on functional and physiochemical properties of turmeric (*Curcuma longa* Linn.) rhizome Var. Kapurkot Haledo-1

Govinda Dhami[1*], Satish Paudel[2] and Saroj Sapkota[3]**

[1]Agriculture Graduates, Purbanchal University, Dhangadhi - 10900, NEPAL
[2]Agriculture Graduates, Agriculture and Forestry University, Surkhet - 21700, NEPAL
[3]Assistant Professor, Agriculture and Forestry University, Department of Agri botany and Conservation Ecology, Chitwan - 44200, NEPAL
[*]Corresponding Author's Email: govindadhami07@gmail.com; [**]Co-corresponding Author's Email: rjsatish123@gmail.com

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ABSTRACT

This study was conducted to evaluate the impact of different processing methods on the functional and phytochemical properties of turmeric rhizomes. The experiment consisted of four treatments: Treatment 1 involved oven-drying the turmeric powder, Treatment 2 involved blanching followed by oven-drying, Treatment 3 involved cooking followed by oven-drying, and Treatment 4 involved sun-drying. Each treatment was replicated four times. The major findings of the study revealed that sun-drying (68.50%) and blanching/oven-drying (66.50%) positively influenced the dispersibility of turmeric powder. Blanching/oven-drying (0.32 g/ml) and cooking/oven-drying (0.30 g/ml) significantly improved the bulk density of turmeric powder ($p<0.001$), with no significant difference observed between these two treatments. The water absorption capacity of the turmeric powders ranged from 3.35 to 5.35 g/ml, with the sun-dried sample displaying the lowest capacity and the cooked/oven-dried sample demonstrating the highest capacity. Similarly, sun-dried powder exhibited the lowest swelling power and solubility, while heat treatment resulted in a substantial increase in both of these parameters. Additionally, the curcumin content was found to be highest in the cooked/oven-dried (3.11%) and sun-dried (2.99%) turmeric powder. In conclusion, this study suggests that blanching and cooking methods have wide applicability in the food industry to enhance the bulkiness of turmeric powder for appropriate packaging and handling. Moreover, these methods contribute to the characteristic flavor and aroma of turmeric. The findings emphasize the importance of considering different processing techniques for optimizing the functional and phytochemical properties of turmeric, thus enabling its effective utilization in various food applications.

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INTRODUCTION

Turmeric (*Curcuma longa*), a perennial herbaceous plant belonging to the ginger family (Zingiberaceae), has been utilized for centuries in various applications such as a condiment, textile dye, and medicinal aromatic stimulant (Yakubu *et al.*, 2015; Enemor *et al.*, 2020). Although native to southern India and Indonesia, turmeric cultivation has expanded to both mainland and island regions of the Indian Ocean. Turmeric rhizomes, characterized by their tough brown skin and bright orange flesh, possess distinctive pungent and bitter characteristics (Igbokwe *et al.*, 2016; Abraham *et al.*, 2018). In Nepal, the National Ginger Research Programme (NGRP) has released two commercial turmeric varieties, namely Kapurkot haledo-1 and Kapurkot haledo-2. Extensive research has explored the nutritional composition of turmeric, revealing its moisture content (8.92%), ash content (2.85%), crude fiber content (4.60%), fat content (6.85%), crude protein content (9.40%), and carbohydrate content (67.38%). Notably, curcumin, a yellow-colored active ingredient, acts as a potent antioxidant and is responsible for turmeric's various biological activities (Ardiah and Wariyah, 2021). Turmeric also contains essential compounds such as vitamin C, beta-carotene, polyphenols, fatty acids, and essential oils (Raji *et al.*, 2010). The quality of agricultural products is influenced by both inherent characteristics and the processing conditions they undergo. Similarly, the quality of turmeric powder is determined by post-harvest processing methods, including boiling, drying, slicing, sun drying, and grinding. However, certain processing techniques, such as sun drying, have been reported to impact color and result in shrinkage, leading to an unappealing final product. To minimize nutrient losses, blanching and chemical treatments have been employed. Furthermore, cooking can alter the physical, chemical, and nutritional properties of food constituents. Despite these considerations, the functional and chemical properties of turmeric rhizomes from Nepal have not been extensively investigated (Iwe *et al.*, 2016; Tamuno, 2020).

Functional properties play a crucial role in assessing the quality and potential applications of turmeric powder. Dispersibility, which measures the hydrophobic action of flour and its ability to separate from water molecules, indicates reconstitution properties. Bulk density, also known as volumetric or apparent density, quantifies the mass of flour particles relative to the total volume they occupy. Water absorption capacity (WAC) refers to the ability of food or flour to absorb moisture, achieving the desired consistency and facilitating high-quality food product creation. Oil absorption capacity (OAC), on the other hand, influences mouthfeel and flavor preservation in food products (Duarte *et al.*, 2017). Additionally, the swelling index (SI) or swelling capacity (SC) measures the volume absorbed by one gram of food material during swelling under specific conditions. Solubility determines the solute's ability to dissolve in a liquid, gaseous, or solid solvent within a food system (Suresh *et al.*, 2007; Ikpeama *et al.*, 2014). The main objective of this study was to evaluate the impact of various processing methods on the functional and phytochemical composition of turmeric rhizomes. Specifically, the study aimed to explore the relationship between functional and physicochemical properties. Additionally, the investigation aimed to examine the relationship among different processing and extraction methods based on phytochemical composition. By addressing the research gap in understanding the effects of processing methods on turmeric rhizomes from Nepal, this study provides valuable insights for optimizing the utilization of turmeric in the food industry and enhancing consumer satisfaction.

MATERIALS AND METHODS

Site and time of the experiment

The study was conducted between October and December 2022 at two different locations: the laboratories of the Centre for Biotechnology, Agriculture, and Forestry University in Chitwan, and the Department of Food Technology and Quality Control in Kathmandu.

Experimental materials

The materials used in the experiment were turmeric rhizomes of variety Kapurkot haledo-1. Four treatments and four replications were used in the CRD method to conduct the experiment.

Treatments details

Treatment 1: Peeled, grated and oven-dried (60 °C for 24 hrs) rhizomes

Treatment 2: Peeled, blanched (10 mins), grated and oven-dried (60 °C for 24 hrs) rhizomes

Treatment 3: Peeled, cooked (1 hr), grated and oven-dried (60 °C for 24 hrs) rhizomes

Treatment 4: Peeled, grated and sun-dried (5 days)

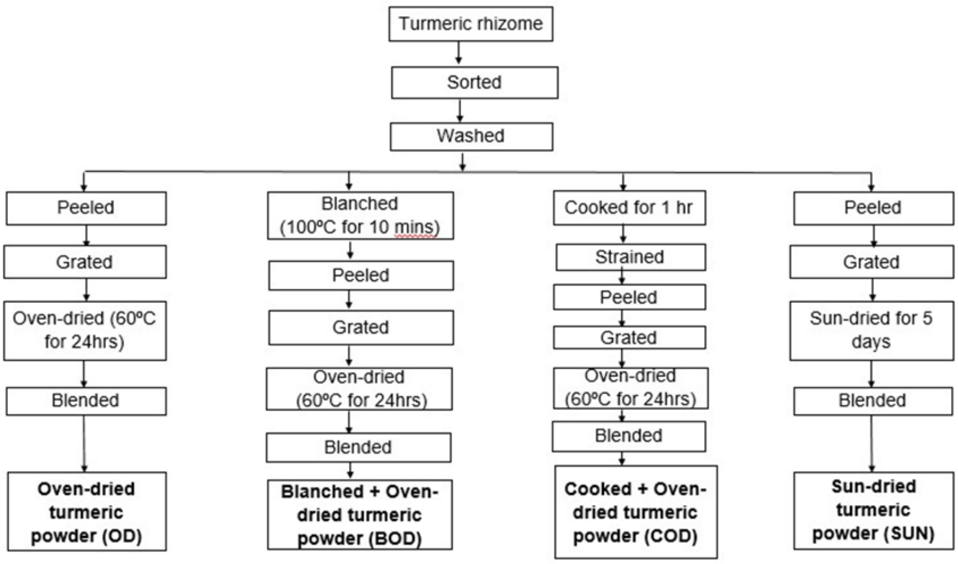

Figure 1. *Schematic diagram of treatment preparation (Tamuno, 2020).*

Preparation of treatments

Functional properties

Dispersibility: Dispersibility was determined by the method of Kulkarni *et al*. (1991). The turmeric sample of 10g was weighed into 100 ml measuring cylinder and distilled water was added to a volume of 100 ml. The set up was stirred vigorously and allowed to settle for three hours. The volume of the settled sediment was recorded as shown on the measuring cylinder and the obtained value subtracted from 100. The difference was reported as percentage dispersibility.

Dispersibility (%) = 100 – Volume of settled sediment

Bulk density: Bulk density was determined by the method described by Narayana and Rao (1984). The sample was poured into a calibrated sample tube. The sample was added till it gets to the 5 ml mark on the tube and then it was weighed again. The tube with the sample was tapped while more samples were added. This continued till the sample was steady at the 5 ml mark of the tube and then the final weight was taken.

$$\text{Bulk density (g/ml)} = \frac{\text{Sample weight after tapping} - \text{Sample weight before tapping}}{\text{5 ml of centrifuge tube}} \text{ X } 100$$

Water absorption capacity

The water oil absorption capacity was determined using the method by Sosulski (1962). One gram of sample was added to 15 ml of distilled water in a pre-weighed centrifuge tube. The centrifuge tube was agitated and centrifuged for 30 minutes at 3000rpm. The clear supernatant was discarded and the volume taken and the tube absorbed water was weighed. The retained water was computed as water absorbed per gram of the sample.

$$\text{Water absorption capacity (g/ml)} = \frac{\text{Initial volume water added} - \text{volume of water decant}}{\text{Sample weight}}$$

Oil absorption capacity: The oil absorption capacity was determined using the method by Sosulski (1962) . One gram of sample was added to 15 ml of canola oil in a pre-weighed centrifuge tube. The centrifuge tube was agitated and centrifuged for 30 minutes at 3000rpm. The clear supernatant was discarded and the volume taken and the tube absorbed oil was weighed. The retained oil was computed as oil absorbed per gram of the sample.

$$\text{Oil absorption capacity (g/ml)} = \frac{\text{Initial volume oil added} - \text{volume of oil decant}}{\text{Sample weight}}$$

Swelling power and solubility: The swelling Power and Solubility was determined using the method by Takahashi and Seib (1988). One gram of the sample was weighed and transferred into a flask and 15 ml of distilled water was added to the sample in the conical flask and shake thoroughly, it was sent to the water bath at a set temperature of 95°C for 1 hour. After heating, it was cooled under running water; it was transferred into a previously dried and weighed centrifuge tube and centrifuge for 30 minutes at 2000 rpm. After centrifuge, the swollen volume was read directly from the tube. The clear portion was transferred into a previously ignited weighed metal can, it was dried in the oven at 105°C for 1 hour after which it was cooled in the dessicator and weighed.

$$\text{Solubility (\%)} = \frac{\text{Weight of solute}}{\text{Sample weight}} \text{ X } 100$$

$$\text{Swelling power} = \frac{\text{Weight of tube} + \text{sediment} - \text{weight of empty tube}}{\text{Sample weight}}$$

Statistical analysis

The collected data were compiled and entered into Ms- excel 2010. Data analysis was done using R version 4.0.1. Analysis of variance for all the observed parameters was carried out as per the procedures given in Agricolae package of R. Duncan`s Multiple Range Test (DMRT) for mean separations was done. Correlogram and dendrogram were prepared using corrplot and factoextra packages of R respectively.

RESULTS AND DISCUSSION

Data obtained from the experiment were analysed and described here under the different headings and sub-headings with appropriate tables and figures wherever necessary.

Effect of processing methods on the functional properties of turmeric powder

Functional properties

Dispersibility (%): Table 1 presents the dispersibility of turmeric powder influenced by different processing methods. The results indicated that the processing methods had a significant impact on dispersibility ($p<0.001$). Dispersibility values ranged from 62.50% in the cooked/oven-dried sample to 68.50% in the sun-dried sample. Sun drying (68.50%) and blanching/oven drying (66.50%) were found to have an improved effect on dispersibility, and these treatments were not significantly different from each other. Similarly, oven drying (64.00%) and cooking/oven drying (62.50%) treatments showed no significant difference between them, and they had a comparatively lesser effect on dispersibility. Dispersibility refers to the ability of flour to disperse and separate from water molecules, indicating its hydrophobic action (Eke-Ejiofor and Kin-Kabari, 2010). Higher dispersibility values are associated with better reconstitution properties (Elkhalifa and Bernhardt, 2013). Based on the present investigation, sun drying has been identified as an effective processing method for enhancing the reconstitution properties of turmeric powder.

Table 1. Effects of different processing methods on functional properties of turmeric rhizome var. Kapurkot haledo-1.

Treatments	Dispersibility (%)	Bulk density (g/ml)	Water absorption capacity (ml/g)	Oil absorption capacity (ml/g)	Swelling power (g/g)	Solubility (%)
OD	64.00[b]	0.21[c]	4.13[b]	1.54[b]	6.64[bc]	21.11[a]
BOD	66.50[a]	0.32[a]	3.92[b]	1.43[bc]	6.92[b]	19.38[b]
COD	62.50[b]	0.30[ab]	5.35[a]	2.00[a]	7.89[a]	16.75[c]
SUN	68.50[a]	0.29[b]	3.35[c]	1.40[c]	6.29[c]	17.29[c]
LSD	2.22	0.02	0.33	0.13	0.36	1.24
p-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
F-test	***	***	***	***	***	***
SEm (±)	0.68	0.01	0.19	0.06	0.16	0.48
CV (%)	2.21	6.49	5.15	5.19	3.39	4.35
Grand mean	65.38	0.28	4.18	1.59	6.93	18.63

***indicates significant at p < 0.001. Means followed by the same letter(s) in the column are not significantly different at 5% by DMRT.OD = Oven Dried turmeric powder; BOD = Blanched + Oven Dried turmeric powder; SUN =Sun Dried turmeric powder; COD = Cooked + Oven Dried turmeric powder.

Bulk density (g/ml): The bulk density of turmeric powder, influenced by different processing methods, is presented in Table 1. The results indicate that the processing methods had a significant effect (p<0.001) on the bulk density. The bulk density of turmeric powders varied from 0.21 g/ml in the oven-dried sample to 0.32 g/ml in the blanched/oven-dried sample. Both blanching/oven drying (0.32 g/ml) and cooking/oven drying (0.30 g/ml) demonstrated a significant (p<0.001) improvement in the bulk density of turmeric powder, with no notable difference between these treatments. On the other hand, sun drying (0.29 g/ml) and oven drying (0.21 g/ml) significantly differed (p<0.001) and had a relatively lower impact on bulk density. The bulk density of flour primarily relies on the particle size and initial moisture content (Tsegaye and Duguma, 2020). The absorption of moisture during the cooking and blanching processes could explain the increased bulk density observed in turmeric powders. This is consistent with findings by Igbokwe *et al.* (2016) in their study on blanched *Dioscorea bulbifera* flour, which reported a similar increase in bulk density. The high bulk density observed in turmeric powders processed with cooking/oven drying and blanching/oven drying indicates their heaviness and suggests their suitability for use in food preparations. Higher bulk densities in flours are desirable as they facilitate ease of dispersibility and reduce paste thickness, as noted by Udense and Eke (2000).

Water absorption capacity (ml/g): Table 1 presents the water absorption capacity of turmeric powder, which was influenced by different processing methods. The results showed a significant effect (p<0.001) of the processing methods on water absorption capacity. The range of water absorption capacity for the turmeric powders was 3.35 - 5.35 g/ml, with the sundried sample exhibiting the lowest value and the cooked/oven dried sample showing the highest. Additionally, the oven dried sample (4.13 g/ml) and the blanched/oven dried sample (3.92 g/ml) had the highest values, with no significant difference observed between these two treatments. The cooking/oven drying treatment demonstrated a significant increase in the water absorption capacity of the turmeric powder. This could be attributed to the denaturation of proteins during the cooking/heat treatment process. Khalid *et al.* (2003) reported that heat-treated flours have a higher tendency to absorb water due to carbohydrate gelatinization and protein denaturation caused by heat. Obatolu *et al.* (2001) also observed that increased cooking time led to the denaturation of yam bean protein, resulting in increased water absorption capacity. Turmeric powders with high water absorption capacity can be employed as food thickeners in various food systems. Therefore, cooked/oven dried turmeric powder can be suitable for this purpose.

Swelling power (g/g): The swelling power of turmeric powder, influenced by various processing methods, is presented in Table 1. The results indicate that the processing methods had a significant impact (p<0.001) on the swelling power. The swelling power ranged from 6.29 g/g to 7.89 g/g, with the sun-dried sample having the lowest value and the cooked/oven-dried sample having the highest value. Similarly, the blanched/oven-dried sample (6.92 g/g) and the oven-dried sample (6.64 g/g) showed the highest values, with no significant difference between these two treatments. The cooking/oven drying treatment was found to significantly enhance the swelling power of the turmeric powders. This improvement could be attributed to the reduction of fat content during the cooking process. According to Yakubu *et al.* (2015), high heat during cooking causes the fat to melt, resulting in a decrease in fat content. Igbokwe *et al.* (2016) further explained that high levels of fat can lead to the formation of amylase-lipid complexes, which restrict the swelling phenomenon. Additionally, the heating process disrupts some of the intermolecular hydrogen bonds, making the swelling more noticeable (Ihekoronye and Ngoddy, 1985).

Solubility (%): Table 1 presents the solubility of turmeric powder affected by different processing methods. The results indicate a significant impact (p<0.001) of these methods on solubility. The lowest solubility was observed in cooked/oven dried and sun-dried samples, with values of 16.75% and 17.29% respectively. The highest solubility of 21.11% was found in the oven dried sample. The blanched/oven dried sample had a solubility of 19.38%, which was significantly different (p<0.001) from the other treatments. In this study, cooking/oven drying, blanching/

oven drying, and sun drying resulted in a significant reduction in the solubility of turmeric powders, while oven drying alone improved solubility. Falade and Okafor (2015) defined solubility as the ability of solids to dissolve or disperse in an aqueous solution, typically water. Based on the obtained results, it can be inferred that the high temperatures used in the oven drying process might have weakened the starch granules, leading to increased solubility.

Physico-chemical properties

Moisture (%): Moisture content of turmeric powder, as affected by different processing methods is presented in Table 2. The processing methods significantly (p<0.001) affected the moisture content. Moisture content ranged from 4.75 – 8.63 % with oven dried sample as the lowest and cooked/oven dried sample as the highest. Similarly, sun dried (6.13 %) and blanched/ oven dried samples (5.13 %) followed the highest value, both the treatments being at par. Higher moisture contents observed in the cooked/ oven dried and blanched/oven dried samples are mainly due to the absorption of water by the turmeric rhizomes during the processes of cooking and blanching. Also, sun dried sample has been found to contain higher moisture content. This could be due to the lower drying days and relatively lower sunlight intensity during the day hours. Moisture gives a measure of the water content of the flour samples. It is also an index of storability of the flour as reduced moisture content implies better shelf life and stability (Eke-Ejiofor and Kin-Kabari, 2010).

Total ash (%): The total ash content of turmeric powder, influenced by various processing methods, is presented in Table 2. The results demonstrate that the processing methods had a significant effect (p<0.05) on the total ash content. The highest total ash content was recorded in oven-dried samples (7.38%) and blanched/oven-dried samples (7.37%), with no significant difference between these treatments. Conversely, the lowest total ash content of 7.10% and 7.03% was observed in cooked/ oven-dried and sun-dried samples, respectively, again with no significant difference between these treatments. The ash content provides insights into the overall amount of inorganic substances, including trace and major minerals, present in the turmeric powder (Hirko *et al*., 2019). Increased boiling duration appears to have a greater impact on the total ash content in the rhizomes. These findings regarding the quality and purity of the turmeric powder align with the findings of Abraham *et al*. (2018), who reported an average ash content of 8.39% as an indicator of sample purity. Additionally, Zerihun *et al*. (2017) reported a total ash content of 13.08% for rhizomes treated at 80°C for 30 minutes, while the lowest ash content of 9.95% was observed in rhizomes boiled at 100°C for 75 minutes.

Curcumin (%): Curcumin content of turmeric powder, as influenced by different processing methods, is presented in Table 2. The results indicate a significant effect (p<0.05) of the processing methods on curcumin content. The highest curcumin content was observed in the cooked/oven dried and sun-dried samples, with values of 3.11% and 2.99%, respectively. These two treatments did not show a significant difference between them. Conversely, the lowest curcumin content was recorded in the blanched/oven dried and oven-dried samples, with values of 2.35% and 2.05%, respectively. These two treatments also did not differ significantly. Curcumin is the primary component responsible for the bright yellow color of turmeric powder, and it is known to be sensitive to heat and light (Raza *et al*., 2018). Therefore, the significant reduction in curcumin content observed in the processed turmeric powders after cooking/ oven drying and sun drying can be attributed to the sensitivity of curcumin. These findings align with the study conducted by Raza *et al*. (2018), which reported that boiling and exposure to sunlight have a significant impact on curcumin concentration. Suresh *et al*. (2007) also reported a loss of 27-53% in curcumin content during heat processing, with the highest loss occurring during pressure cooking for 10 minutes.

Table 2. Effects of different processing methods on physic-chemical properties of turmeric rhizome var. Kapurkot haledo-1.

Treatments	Moisture (%)	Total ash (%)	Curcumin (%)	pH
OD	4.75[c]	7.38[a]	2.05[b]	6.92[b]
BOD	5.13[bc]	7.37[a]	2.35[b]	6.75[b]
COD	8.63[a]	7.10[b]	3.11[a]	6.75[b]
SUN	6.13[b]	7.03[b]	2.99[a]	7.25[a]
LSD	1.03	0.27	0.32	0.26
p-value	<0.001	0.0277	<0.001	0.00356
F-test	***	*	***	**
SEm(±)	0.42	0.05	0.12	0.06
CV(%)	10.81	2.42	7.79	2.42
Grand mean	6.16	7.22	2.63	6.92

*, ** and *** indicate significant at p < 0.05, p< 0.01 and p< 0.001 respectively. Means followed by the same letter(s) in the column are not significantly different at 5% by DMRT. OD = Oven Dried turmeric powder; BOD = Blanched + Oven Dried turmeric powder; SUN = Sun Dried turmeric powder; COD = Cooked + Oven Dried turmeric powder.

pH: The pH values of turmeric powder, influenced by different processing methods, are presented in Table 2. The processing methods had a significant impact on the pH value ($p<0.01$). The pH values of the turmeric powders were highest in the oven-dried (6.92), blanched/oven-dried (6.75), and cooked/oven-dried (6.75) samples, with no statistically significant difference among these treatments. The sun-dried sample recorded the highest pH value of 7.25, which was statistically significant ($p<0.01$) compared to the other treatments. The pH of a food product is closely related to the development of a pleasant taste (Niba, 2001). Moreover, pH plays a crucial role in the formation of flavor and aroma characteristics in foods, as well as determining the stability of the food product (Ardiah and Wariyah, 2021). The high pH value observed in sun-dried turmeric powder is undesirable as it may increase the susceptibility of the product to bacterial spoilage. Generally, turmeric water has a pH value closer to neutral (pH 7)

Association among functional and physico-chemical properties

The correlogram depicting the association among the functional and physico-chemical properties of turmeric rhizome powder is presented in Figure 2. The analysis revealed a strong positive correlation of 0.93 between water absorption capacity and oil absorption capacity, both of which are functional properties. Conversely, the lowest negative correlation value of -0.74 was observed between dispersibility and pH. In general, the pairs among the functional properties and among the physico-chemical properties exhibited positive correlations, while the pair involving the correlations between functional and physico-chemical properties displayed weak positive correlations and/or negative correlations.

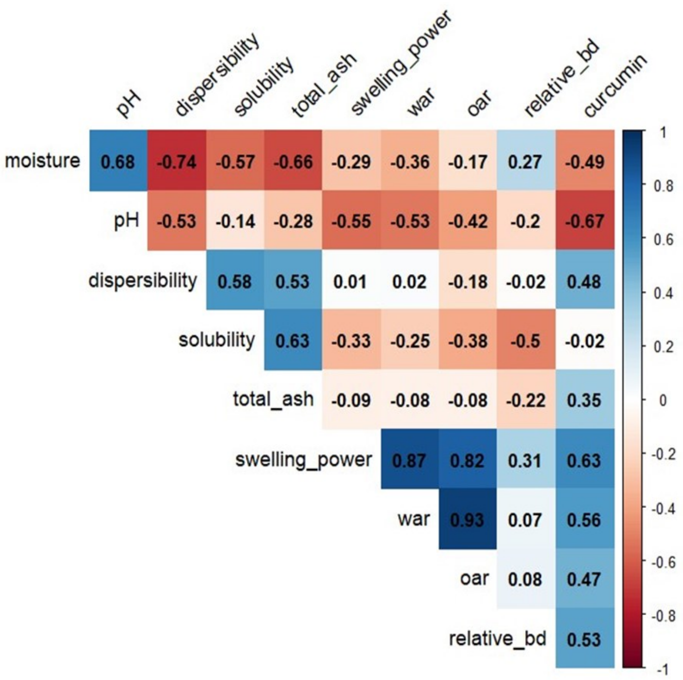

Figure 2. *Correlogram showing the relationship between functional and physio-chemical properties of turmeric rhizome powder var. Kapurkot haledo-1.*

Conclusion

The completion of this experiment has revealed the effectiveness of blanching and cooking/oven drying in improving the bulk density, swelling power, and water and oil absorption capacities of turmeric. As a result, these two processing methods can be widely utilized in the food industry to enhance the bulkiness of turmeric powder for proper packaging and handling, as well as to infuse characteristic flavor and aroma into food products. The higher solubility observed in oven-dried powder and the increased dispersibility in sun-dried powder can be attributed to the improved hydrophilic and reconstitution properties of turmeric powder, respectively. Considering the heat sensitivity of curcumin, a key component in turmeric, employing low heat and low-pressure cooking methods can effectively preserve its maximum properties. Correlogram analysis indicates positive correlations among functional properties and among physico-chemical properties. However, the correlations between functional and physico-chemical properties show weak positive correlations and, in some cases, negative correlations.

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