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Original Article

Impact of dehydration temperature on the nutritional, phytochemical and volatile flavor profile of mango (*Mangifera indica* L.) varieties from the subtropical region of Pakistan

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Abstract

Mango (*Mangifera indica* L.), a member of the Anacardiaceae family, is widely known as the "King of Fruits" due to its unique flavor and taste. Pakistan ranks among the top ten mango-producing countries; however, less than 10% of total production is exported, and up to 70% is lost at postharvest level, limiting its market value. This highlights the need for mango valorization through value addition to reduce losses and increase economic returns. In this study, major mango varieties of subtropical region of Pakistan (Chaunsa, Sindhri, and Fajri) were processed using dehydration technology. Fruits were graded, washed, peeled, and sliced before drying in a hot air dehydrator at 50 °C, 60 °C, and 70 °C. Both fresh and dried samples were analyzed for nutritional composition, phytochemicals, and volatile flavor compounds using GC-MS. Sindhri exhibited higher ash (0.48±0.01%) and mineral content, while Chaunsa showed superior phytochemical and flavor profiles with 175.00±1.73 mg GAE/100g of total phenolic contents and 77.67±0.33% antioxidant activity. Identified volatile compounds included aldehydes, ketones, terpenes, alcohols, and esters, contributing to mango's characteristic aroma. Major compounds detected were acetic acid, butanone, furanmethanol, and glyceraldehyde. Butane derivatives varied across varieties, including butanediol (Fajri), butyrolactone (Chaunsa), and 1-butanol (Chaunsa and Sindhri). Drying temperature significantly affected flavoring profile. Some compounds were lost, while others transformed into new compounds, with the most pronounced changes occurring at 70 °C. Overall, drying at 50–60 °C was found optimal for producing dehydrated mango slices with maximum retention of flavors, nutrients and acceptability.

Keywords: Dehydration, Volatile compounds, Flavoring compound, Phenolics

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Introduction

The Mango (*Mangifera indica* L.) belonging to *Anacardiaceae* family is a tropical fruit with various varieties and health promoting properties. It contains different nutrients like fiber, phytochemicals, vitamins, carotenoids, minerals and phenolics which are distributed in various parts of mango fruit (Gupta and Jain, 2014). Mango is also known as "*King of Fruits*" because of its taste, flavor and different health benefits. It is used unripe as well as ripe form directly or different processed food products including jam, pickles, squashes, chutneys and desert flavoring (Mubarik et al., 2020). Due to its taste, flavor and nutritional value, the demand of fresh as well as processed mango is high throughout the world (Mubarik et al., 2020). Mango is also a good source of phytochemicals having antioxidative, wound healing, anti-inflammatory, antimicrobial, anti-tumor and hypolipidemic effects (Imran et al., 2017). Phenolic compounds are secondary phytometabolites that constitute an important component of human diet and have a significant importance due to their health promoting and biological properties (Yahia et al., 2017). Hydroxycinnamic and hydroxybenzoic (derivatives of phenolics) are found in mango pulp and reflect the healthy nature of mango (Burton-Freeman et al., 2017).

Globally, 50.6 million tons of mangoes were produced in 2024 from 5.7 million hectares (ha) area. Under the cultivation of mango, Pakistan shares about 3% of the total global area for cultivation and contributes about 3.3% of the total production. The production of mango (per ha) in Pakistan is about 12% greater than the average world production. In export, Pakistan contributes about 5% of mango export internationally and earns two third of the global average export price (FAOSTAT, 2024).

Pakistan is at 6th position in the mango producing countries with the production yield of 1717 thousand tons, cultivated on 171 thousand ha area. Punjab and Sindh are two main provinces of Pakistan in the production of mango with 97% share in the average yield of the country. Punjab contributes 63% and Sindh contributes 34% in mango production of Pakistan. About 1360 varieties of mango exists in the world and Pakistan produces 150 varieties and fruits vary in their shape, color, acidity, size, physiological properties and harvesting time. Among the mango varieties grown in Pakistan, Chaunsa and Sindhri are the dominant while other major varieties include Fajri, Langar, Saroli, Anwar Ratol, Duseri and Beganpali. So, the two most famous and delicious varieties of Pakistan are Chaunsa and Sindhri. The Chaunsa and Sindhri are famous varieties and are highly acceptable to consumer as well as industry which ultimately increases the demand of these varieties not only at national level but also at international level (Mazhar and Muhammad, 2011).

In Pakistan, although the production of mango fruit is enough not only to meet the domestic/national requirement but also to fulfil the export demand. But unfortunately, less than 10 percent of mango is exported and about 72 percent of mango fails to reach higher market value due to poor post-harvest management (Collins and Iqbal, 2011). In the local market, it has been observed that about 25% of fruit is diseased, 14% sap burned and 58% damaged by improper physical handling. The maximum losses or waste occur because of improper processing techniques, post-harvest handling and post storage techniques and marketing (Mazhar and Muhammad, 2011).

To maintain fruit freshness and nutritional value, there should be proper post-harvest management like transportation, packaging, and handling. At the same time, there is also a need for value addition and preservation of the fruit for round the year availability and to reduce the losses. For this purpose, different preservation and value addition techniques are used worldwide in order to get maximum financial return for agricultural produce. Among these techniques, the dehydration technology (removal of water) is getting popularity day by day because of long shelf life of the products due to reduced moisture levels. The removal of water can be achieved through different drying techniques like freeze drying, microwave drying, vacuum drying, osmotic dehydration, infrared drying, sun drying and hot air drying (Rahman, 2020). Each process/technique has advantages as well as some limitations. Drying by use of high temperature is considered as a suitable technique for the preservation of fruits and vegetables (Hasan et al., 2019). The benefits associated with drying include decrease in weight and volume, reduced storage cost, reduced packaging cost, and easy transportation along with availability of product throughout the year or during off season. Moreover, the products developed through drying process serve as snacks which are good in nutrition and healthier alternative to other chemically processed products like sweets and starch-based snacks (Sehrawat et al., 2018). The dehydrated fruits

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are famous all over the globe and have a good share in high value market chains.

Keeping in view the mango production in Pakistan, postharvest losses and its market value, the current research work was conducted for the value addition of mango in order to reach high value markets for maximum financial return. The hot air-drying technique was used for the development of dehydrated mango snacks and the effect of drying temperature on flavoring profile was assessed for the optimization of the drying temperature.

Material and Methods

The study was performed in the Department of Food Science & Technology and Central Lab System, Muhammad Nawaz Shareef University of Agriculture Multan (MNSUAM), Pakistan. The chemicals used were of analytical grade (oxide) and purchased from the local market.

Procurement of mango

The fully ripened mango varieties Sindhri (VS), Chaunsa (VC) and Fajri (VF) were purchased from Lutfabad Fruit Farm, Multan (subtropical region), Pakistan.

Preparation of mango slices

The ripened mangoes were washed under tap water and after grading into uniform size, the fruits were manually peeled by using knives. After peeling, the uniform slices (6 mm – 9 mm thickness) were prepared manually. The slices were blanched in 10% sugar solution (with a lower brix than mango pulp) followed by 3-4 minutes dipping in 3% potassium metabisulfite aqueous solution.

Dehydration of mango

Mango slices were dehydrated by using hot air dehydrator (PAMICO Technology, Faisalabad, Pakistan) at 50, 60 and 70 ℃ till a moisture content of 10-12 percent (Table 1). After dehydration of mango, the dehydrated slices were unloaded, cooled and then evaluated for the below given quality parameters.

Table-1. Moisture contents of fresh and dried mango.

Variety	Fresh/Raw	Dehydrated mango slices at different temperatures		
		50	60	70
Chaunsa	79.11±0.18	11.444±0.004[a]	11.437±0.006[a]	11.446±0.006[a]
Sindhri	78.78±0.15	11.442±0.00 [a]	11.437±0.006[a]	11.443±0.004[a]
Fajri	79.62±0.27	11.444±0.004[a]	11.437±0.006[a]	11.440±0.002[a]

*Values with same letter in a row or column are statistically similar ($p \leq 0.05$).

Proximate composition

Fresh and dehydrated mango samples were subjected to proximate analysis including moisture, crude protein, crude fat, crude fiber, and ash contents by following the protocols of AOAC (2016).

Total phenolic content

The phenolic contents were checked by Folin-Ciocalteu's method as followed by Jiang et al. (2021). For the accomplishment of the purpose, the methanolic extract was made by adding 10mL methanol solution and 1g of sample in the tube followed by vigorous shaking and the processes of centrifugation for 4 minutes at 15000 rpm. Centrifugation resulted in the separation of sediments and supernatant (collected for further analyses). For reagents preparation, 20g of phosphomolybdic acid and 100g sodium tungstate were dissolved in the 750mL distilled water and then 50mL of phosphoric acid was added in the solution. The mixture was refluxed for two hours by adding water to a volume of 1L.

In a separate test tube, 100µL of mango sample, 0.5mL Folin-Ciocalteu's reagent and 10mL of distilled water were taken and mixed well in the orbital shaker for 5-7 minutes. Then, 1.5mL of 20% sodium bicarbonate and 7mL of distilled water were taken in the test tube. The prepared sample was incubated in dark for 60 minutes at 40 °C. Spectrophotometer (UV visible, Cecil, 7400S, UK) was operated at 725 nm and blank without Folin reagent was also run. After calibration, the sample was also run at 725 nm. To obtain the curve, Gallic acid standard having a range of 0.01-0.05% Gallic acid solution was also run along with sample. Phenolic contents were measured by using the formula:

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$$\text{Total Phenolic contents (mg GAE/100g)} = C \times \frac{V}{M}$$

Whereas,
C = Gallic acid concentration (mg/mL)
V = Extracted sample weight
M = Methanolic extract sample weight.

Antioxidant activity

The antioxidant activity of DPPH (1,1-diphenyl-2-picrylhydrazyl) was measured by the absorbance of spectrophotometer with standard methanol DPPH solution as described by Mishra et al. (2020) with slight changes. The methanolic extract of the sample (fresh and dehydrated mango) was prepared at first by vigorous shaking of 1g of sample with the methanol followed by the centrifugation at 15000 rpm for 5 minutes. Then the solution of DPPH was made by adding 3mg of DPPH and 100mL methanol. Then, in a separate test tube, 50µL of the sample and 2mL of DPPH solution was added and shaken thoroughly for 1 hour in orbital shaker. For reaction completion the sample solution was kept at room temperature in the dark. At the end, the absorbance was checked at 515 nm on spectrophotometer. Blank was also run. The following formula was used for the estimation of antioxidant activity:

$$\text{DPPH radical scavenging capacity (\%)} = \frac{AB - AA}{AB} \times 100$$

Whereas,
AB = Blank sample absorbance at time t = 0 min.
AA = Extracted solution absorbance at time t = 15 minutes.

Microbial analysis

Microbial analyses were performed by using the protocol for Total Plate Count (TPC) as prescribed by Harrigan (1998) and Pikkemaat et al. (2007). Plate Count Agar was used for bacterial growth. The medium was sterilized by autoclaving (121°C for 15 minutes) while glassware was sterilized in a hot air oven at 171°C for 30 minutes. Sample (1 g) was taken and diluted through 10-fold serial dilutions. Incubation was carried out at 37 °C for 24-48 h. Plates were removed after the incubation process and then the colonies were counted with the TPC calculated as follows:

$$\text{Viable count} = \frac{\sum C}{(n1 + 0.1n2) * d}$$

Whereas,
C = Number of colonies
n_1 = Number of plates from the lowest selected dilution
n_2 = Number of plates from the highest selected dilution
d = Dilution factor of lowest selected dilution.

Yeast and mold analysis

The analysis of yeast and mold was also performed by following the above-mentioned procedure recommended by Harrigan (1998). The medium used was Yeast Mold Agar (YM Agar) and the incubation temperature was 30 °C.

Color analysis

Color is an important parameter in the product. Color was measured using Handheld portable calorimeter (CR-400 Chromometer, Konika Minolta, Japan). Data was stated in the L*, a* and b* color notation system determined with standard protocol given by Frederick and Bethke (2019).

Flavoring compounds

Dehydrated and fresh mango sample (5g) with 1.5g of NaCl were blended and stirred at 80rpm speed in 15ml vials. The vials were then shifted into glass tube and subjected to extraction for 30 minutes with heating at 40 °C and continuous stirring/mixing. After that, the sample was taken and introduced into GC for desorption and analysis.
For analysis of flavoring compounds, GC-MS (model no: Agilent-8890 GC system/5977B GC-MSD) was used having DB-WAX column for sample separation. Helium as a carrier gas was used with speed of 1.7mL/min and split-less inlet of GC was set. Temperature of injector in GC was 250 °C. Program of GC temperature was 40 °C (hold for 2 minutes) to 160 °C at 4 °C/min and raised to 280 °C at 50 °C/min. Temperature for ion source was 230 °C and range of mass was from m/z 35 to 450. The volatile compound and organic acids were scanned by using NIST-20 library (Haocheng et al., 2020).

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Statistical analysis

All the data of current research was analyzed by mean values as well as standard deviation using the prescribed method of Montgomery (2017).

Results

Proximate composition

The analysis of raw mango indicated that the Fajri variety (FV) contained 79.62±0.27% moisture, crude protein 0.93±0.02%, fat 0.52±0.02%, 0.87±0.02% crude fiber and 0.35±0.01% ash. The Chaunsa variety (CV) contained 79.11±0.18% moisture, protein 0.91±0.02%, 0.42±0.02% fat, fiber 0.81±0.01%, 0.44±0.01% ash. Whereas the research revealed that the Sindhri variety (SV) contained 78.78±0.15% moisture, 0.94±0.01% protein, 0.48±0.02% fat, 0.82±0.03% fiber and 0.48±0.01% ash (Figure 1).

The mango slices were dried at about 10-12% moisture contents so the mean moisture contents of dehydrated slices, irrespective of variety was 11.40%. There was significant effect of dehydration temperature on protein and fat contents of the mango slices. The protein and fat contents of dried slices were ranged from 1.08±0.001 to 1.12±0.01% and 1.14±0.01 to 1.33±0.001%, respectively. Similarly, the ash and fiber contents were ranged from 3.22±0.004 to 3.25±0.004% and 2.39±0.001 to 2.41±0.001%, respectively (Figure 1). The higher contents of all parameters in dried mango slices were due to removal of water.

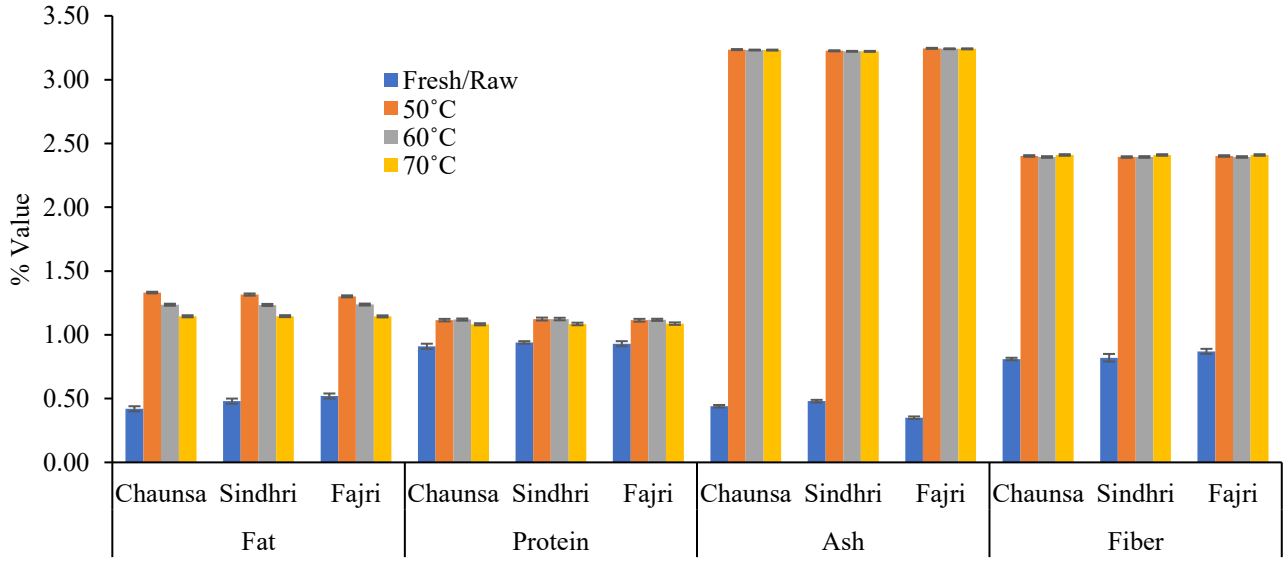

Figure-1. Proximate composition of fresh and dried mango varieties.

Total phenolic content

The phenolic contents of raw/fresh mango indicated that Chaunsa variety (CV) contained 175.00±1.73 mg GAE/100g, Sindhri variety (SV) contained 134.33±2.33 mg GAE/100g and the Fajri variety (FV) contained 116.67±0.88 mg GAE/100g of phenolic contents. Although, the effect of temperature on total phenolic contents of dehydrated mangoes indicated that the total phenolic contents were significantly declining with drying temperature. There was a regular decline in phenolic contents with increasing temperature irrespective of the variety. The mean total phenolic contents were ranged from 62.21±0.001 mg GAE/100g to 88.83±0.001 mg GAE/100g due to dehydration temperature (Figure 2).

Antioxidant activity

Antioxidant activity analysis was performed to check the varietal effect of raw as well dry mango and impact of drying/dehydration temperature. The study showed that the Fajri variety (FV) possessed 73.33±0.88% antioxidant activity, Chaunsa possessed 77.67±0.33%, whereas the Sindhri variety (SV) showed 72.00±0.58% antioxidant activity in fresh/raw mango. The effect of temperature on antioxidant activity of dehydrated mangoes indicated a significant decline

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with drying temperature in all varieties. The mean antioxidant activity ranged from 33.27±0.01% to 58.83±0.01% when processed through different temperatures as shown in Figure 2.

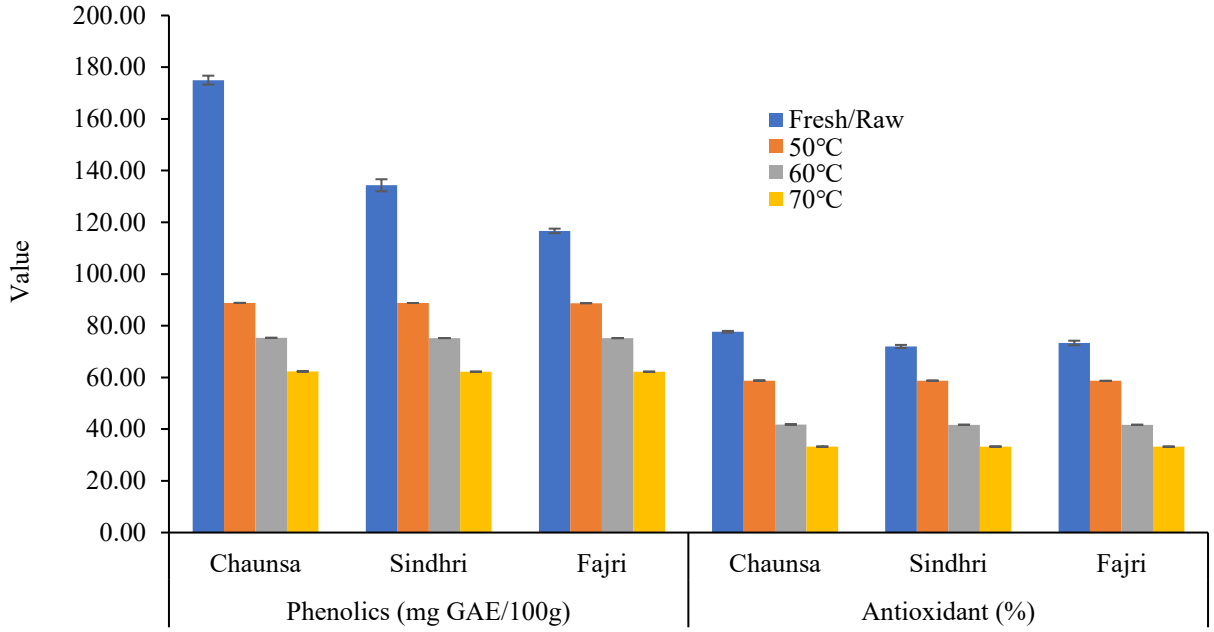

Figure-2. Phytochemicals and antioxidants in fresh and dried mango varieties.

Microbial analysis

The results for microbial (viable bacterial count) bacterial count are shown in Figure 3. The study showed that the Fajri variety (FV), Chaunsa variety (CV) and Sindhri variety (SV) of fresh mango contained 4.20±0.17 log10 cfu/g, 4.15±0.22 log10 cfu/g and 4.13±0.23 log10 cfu/g viable bacteria. Although the effect of temperature on bacterial count of dehydrated mangoes indicated non-significant results however, the mean bacterial count was ranged from 3.55±0.01 log10 cfu/g to 3.67±0.01 log10 cfu/g when processed through different temperatures with no significant differences among varieties.

Yeast and mold analysis

Yeast and mold analysis as given in Figure 3, revealed that the effect of temperature and variety on YMC of dehydrated mangoes was found to be highly significant. The mean YMC of the slices dried at different temperatures ranged from 2.09±0.01 log10 cfu/g to 3.20±0.01 log10 cfu/g. The highest YMC was observed in Fajri variety dried at 50°C while significantly the lowest count was observed in slices prepared from Sindhri variety through dehydration at 70°C.

Color analysis

Color analysis was performed to check the lightness, redness and yellowness of color in three different varieties of raw mango and results of all varieties. The study indicated that the lightness levels (L* value) of Fajri, Chaunsa and Sindhri varieties were found to be 58.25±0.09, 58.43±0.17 and 58.51±0.15, respectively. Similarly, the redness level (a* value) was found to be higher in Fajri variety with mean value of 12.22±0.05 followed by Sindhri with mean value of 12.21±0.05. Whereas the lower redness was observed in the pulp of Chaunsa variety with mean value of 12.14±0.04. In case of yellowness (b* value), it was observed that the intensity of yellow color was 52.47±0.19, 52.49±0.09 and 52.54±0.11 in case of Fajri, Chaunsa and Sidhri varieties, respectively.

The effect of temperature on color values of dehydrated mangoes indicated a significant variation due to changes in temperature in all varieties. The lightness and yellowness were highest at 50˚C and lowest at 70˚C, while redness was increased with increasing temperature and was found to be highest at 70˚C in all the varieties as shown in Figure 4.

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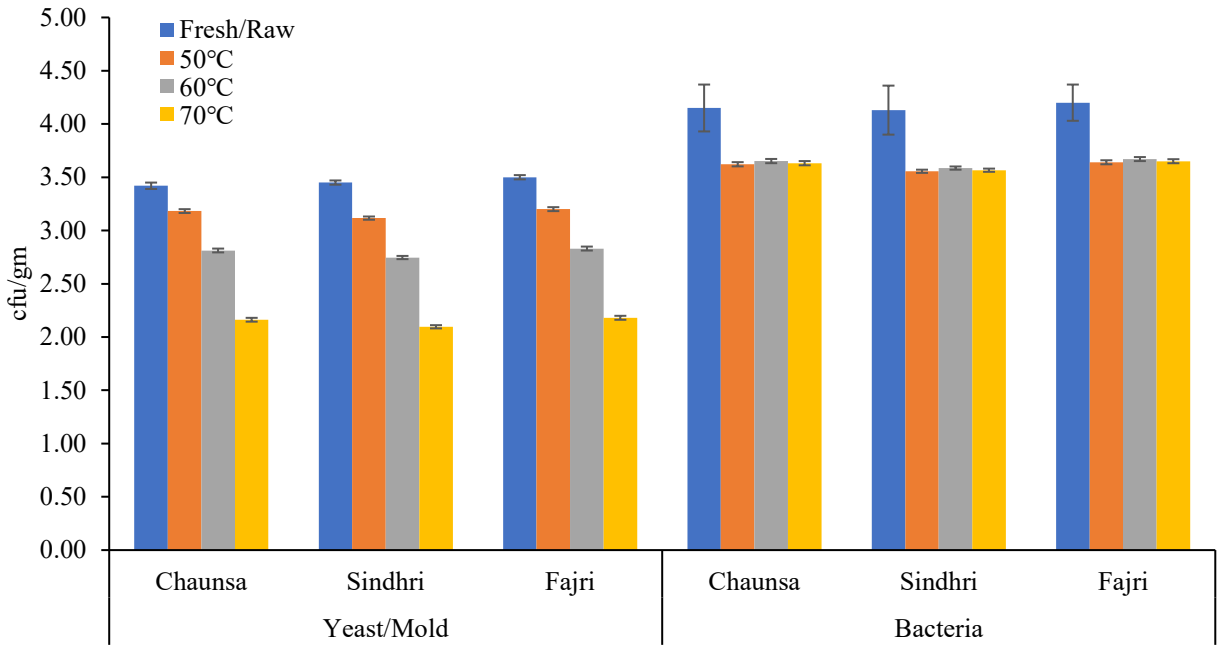

Figure-3. Microbial analysis of fresh and dried mango varieties.

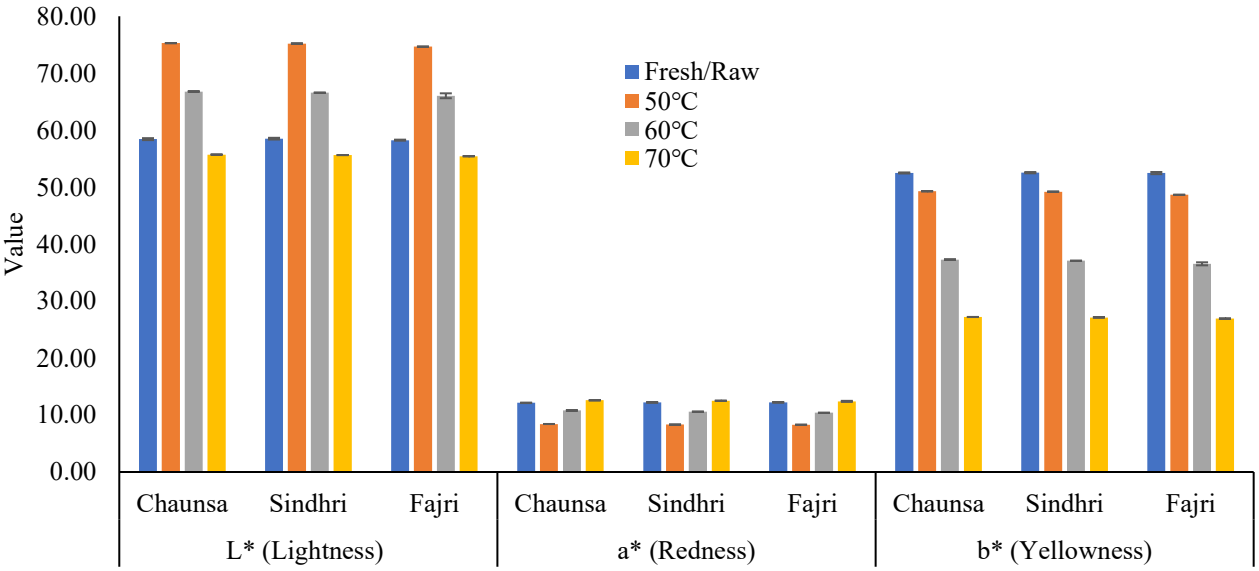

Figure-4. Color analysis of fresh and dried mango varieties.

Flavoring compounds of fresh mango varieties

The comparison of volatile/flavoring compounds in the selected varieties of mango collected from sub-tropical regions are given in Table 2. The volatile compounds detected in Chaunsa variety as per descending order of retention time were n-Hexadecanoic acid, 4-Acetylbenzoic acid, Isopropyl-beta.-D-thiogalactopy, Hydroxy dimethylprop-2, Sucrose, Glyceraldehyde, Butyrolactone, 2-Propanone, 2-Furanmethanol, Oxalic acid, Propanoic acid, Glycerin, 1-Butanol, Acetic acid, hydrazide, Dihydroxyacetic acid and Dimethyl ether. Similarly,

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the descending order as per retention time of volatile compounds in Sindhri and Fajri varieties was Ethyl ester, 17-Pentatriacontene, Sucrose, Monomethyl malonate, 5-Acetoxymethyl-2-furaldehyde, Furan, 2-methyl-5-(methylthio), Piperazine, 1,4-dimethyl, 3-Amino-2-oxazolidinone, Glyoxal, 1-Butanol, Furanmethanol, 3-Furaldehyde, Acetic acid, Glycerin, Propane, 2-fluoro-2-methyl, 2-Propanone and Methylnonanoic acid, N-Methoxymethyl, Sucrose, Thiophene, 2-Chlorophenol, Cyclobutanemethanol, 2-Pyrolidinone, 1,4-Butanediol, respectively. Results indicated that the varieties of volatile compounds were higher in Chaunsa followed by Sindhri, whereas the least number of volatile compounds were detected in Fajri variety. The volatile compounds, 1-Butanol, 2-Propanone, Acetic acid and Glycerin were found to be common in Chaunsa and Sindhri variety whereas, the profile of Fajri variety was totally different.

Table-2. Volatile compounds of Chaunsa, Sindhri and Fajri varieties (fresh).

Compound	Chaunsa		Sindhri		Fajri	
	RT	PA	RT	PA	RT	PA
1,4-Butanediol	-	-	-	-	4.153	9.41
Butyrolactone	8.402	1.01	-	-	-	-
Cyclobutanemethanol			-	-	12.332	1.51
1-Butanol	4.064	0.04	8.813	0.32	-	-
2-Furanmethanol	6.886	0.87	-	-	-	-
Furan, 2-methyl-5-(methylthio)	-	-	14.012	0.52	-	-
Furanmethanol	-	-	6.63	1.63	-	-
3-Furaldehyde	-	-	5.71	1.78	-	-
5-Acetoxymethyl-2-furaldehyde	-	-	20.277	0.09	-	-
2-Propanone	7.22	1.78	3.407	2.4	-	-
Hydroxy dimethylprop-2	36.559	0.12	-	-	-	-
Isopropyl-.beta.-D-thiogalactopy	36.674	0.06	-	-	-	-
Propane, 2-fluoro-2-methyl	-	-	4.136	3.22	-	-
Propanoic acid	5.191	0.87	-	-	-	-
2-Pyrolidinone	-	-	-	-	8.789	2.46
3-Amino-2-oxazolidinone	-	-	11.85	0.44	-	-
Acetic acid	-	-	5.387	0.77	-	-
Acetic acid, hydrazide	3.396	0.07	-	-	-	-
Dihydroxyacetic acid	3.322	1.44	-	-	-	-
Dimethyl ether	3.22	0.81	-	-	-	-
Ethyl ester	-	-	37.252	5.76	-	-
Glyceraldehyde	10.084	0.08	-	-	-	-
Glycerin	4.574	1.7	4.181	1.65	-	-
Glyoxal	-	-	9.163	0.43	-	-
Methylnonanoic acid	-	-	-	-	37.323	0.41
Monomethyl malonate	-	-	20.784	0.11	-	-
N-Methoxymethyl	-	-	-	-	33.923	0.15
Piperazine, 1,4-dimethyl-	-	-	12.059	0.4	-	-
Thiophene	-	-	-	-	20.941	0.04
17-Pentatriacontene	-	-	33.204	0.06	-	-
n-Hexadecanoic acid	37.26	7.5	-	-	-	-
2-Chlorophenol	-	-	-	-	14.227	3.32
4-Acetylbenzoic acid	36.961	0.53	-	-	-	-
Oxalic acid	5.542	1.24	-	-	-	-
Sucrose	29.634	0.14	29.674	0.13	29.674	0.13

RT: Retention Time (Minutes) PA: Peak Area (%)

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Flavoring compounds of dehydrated mango varieties

The variation/changes in volatile/flavoring compounds of Chaunsa variety due to dehydration temperature are shown in Table 3. The results indicated that there were significant changes in volatile compounds due to exposure of slices under different temperature conditions. The losses in volatile/flavoring compounds were higher at 70 °C while stable at 50 °C and 60 °C. It was observed that the Dimethyl ether, Acetic acid, hydrazide, 1-Butanol, Glyceraldehyde, Sucrose, Hydroxy-dimethylprop-2, Isopropyl-.beta.-D-thiogalactopy, 4-Acetylbenzoic acid and Oxalic acid were found to be highly sensitive and were evaporated or converted into other compounds even at 50 °C. Dihydroxyacetic acid remained stable at 50 °C but was not detected in mango slices dried at 60 °C. The volatile compounds which were retained under dehydration temperature of up to 70 °C were Glycerin, Propanoic acid, 2-Furanmethanol, 2-Propanone, Butyrolactone and n-Hexadecanoic acid whereas, the new detected volatile/flavoring compounds were Methyl glyoxal, Propanamide, 2-hydroxy, 1,2-Ethanediol, Cyclohexanone, 2,5-Furandione, 2-Chloro-1-propanol, Cyclopentanol, Guanazine, 3-Cyclohexen-1-carboxaldehyde, Oxypurinol, Pyridinone and Melezitose.

Table-3. Volatile compounds of Chaunsa variety.

Compound	Fresh Fruit (raw)		Dehydration Temperature					
			50°C		60°C		70°C	
	RT	PA	RT	PA	RT	PA	RT	PA
Dimethyl ether	3.220	0.81	-	-	-	-	-	-
Dihydroxyacetic acid	3.322	1.44	10.742	0.34	-	-	-	-
Acetic acid, hydrazide	3.396	0.07	-	-	-	-	-	-
1-Butanol	4.064	0.04	-	-	-	-	-	-
Glycerin	4.574	1.70	3.735	0.88	3.607	1.08	3.289	3.12
Propanoic acid	5.191	0.87	4.987	2.22	5.323	1.82	4.036	4.47
Oxalic acid	5.542	1.24	-	-	-	-	-	-
2-Furanmethanol	6.886	0.87	6.585	1.01	6.757	0.09	6.720	0.17
2-Propanone	7.220	1.78	3.289	2.53	6.607	1.22	6.943	0.30
Butyrolactone	8.402	1.01	8.182	0.72	7.075	0.42	7.060	1.00
Glyceraldehyde	10.084	0.08	-	-	-	-	-	-
Sucrose	29.634	0.14	-	-	-	-	-	-
Hydroxy dimethylprop-2	36.559	0.12	-	-	-	-	-	-
Isopropyl-.beta.-D-thiogalactopy	36.674	0.06	-	-	-	-	-	-
4-Acetylbenzoic acid	36.961	0.53	-	-	-	-	-	-
n-Hexadecanoic acid	37.260	7.50	37.030	11.53	14.293	0.13	14.273	2.33
Methyl glyoxal	-	-	4.037	5.89	8.185	0.14	8.792	1.72
Propanamide, 2-hydroxy	-	-	4.118	0.06	-	-	-	-
1,2-Ethanediol	-	-	6.938	0.26	8.884	0.07	9.154	0.44
Cyclohexanone	-	-	8.751	1.86	8.812	0.08	-	-
2,5-Furandione	-	-	9.148	0.47	-	-	-	-
2-Chloro-1-propanol	-	-	11.027	0.85	-	-	-	-
Cyclopentanol	-	-	12.336	1.00	12.739	0.07	-	-
Guanazine	-	-	13.707	0.56	13.265	0.04	12.341	0.72
3-Cyclohexen-1-carboxaldehyde	-	-	16.229	0.26	18.634	0.28	-	-
Oxypurinol	-	-	17.701	0.03	17.343	0.07	17.140	2.80
Pyridinone	-	-	21.680	0.35	20.646	0.44	25.292	0.25
Melezitose	-	-	30.747	0.39	37.213	2.58	33.384	0.08

RT: Retention Time (Minutes) PA: Peak Area (%)

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In case of Sindhri variety, Glycerin, 3-Amino-2-oxazolidinone, Furan, 2-methyl-5-(methylthio) were found to be the most stable volatile/flavoring compounds and were detected in mango slices dehydrated at a temperature of up to 70 °C whereas, 2-Propanone, Acetic acid, Furanmethanol and Ethyl ester were found to be stable at a temperature of up to 60 °C. At an exposure of temperature of 50 °C, 5-Acetoxymethyl-2-furaldehyde, and Monomethyl malonate were found to be stable while, 3-Furaldehyde, Propane, 2-fluoro-2-methyl, 1-Butanol, Glyoxal, Piperazine, 1,4-dimethyl and 17-Pentatriacontene were found to be highly sensitive and were not detected after a heat treatment of 50°C. Moreover, Methyl glyoxal, Butyric acid, 4-Penten-2-one, 4-methyl, 1-Hepten-4-ol, 2-Hexanone, 1,3-Dioxane, 2-ethyl-5-methyl, Oxirane, 2,2-dimethyl-3-propyl, 2-Butanone, Catechol, 2,3-Dimethyldecane and Sucrose were newly detected compounds in the slices prepared through dehydration of mango slices at a temperature of up to 70 °C and most of these compounds were not detected in slices dehydrated at higher temperature as shown in Table 4.

Table-4. Volatile compounds of Sindhri variety.

Compound	Fresh Fruit (raw)		Dehydration Temperature					
			50°C		60°C		70°C	
	RT	PA	RT	PA	RT	PA	RT	PA
2-Propanone	3.407	2.40	3.962	1.22	3.814	1.42	-	-
Propane, 2-fluoro-2-methyl	4.136	3.22	-	-	-	-	-	-
Glycerin	4.181	1.65	4.241	0.10	3.914	1.38	4.482	2.34
Acetic acid	5.387	0.77	10.315	0.08	11.32	0.03	-	-
3-Furaldehyde	5.710	1.78	-	-	-	-	-	-
Furanmethanol	6.630	1.63	6.757	0.09	6.250	0.79	-	-
1-Butanol	8.813	0.32	-	-	-	-	-	-
Glyoxal	9.163	0.43	-	-	-	-	-	-
3-Amino-2-oxazolidinone	11.850	0.44	7.738	0.02	7.722	0.26	7.22	0.24
Piperazine, 1,4-dimethyl-	12.059	0.40	-	-	-	-	-	-
Furan, 2-methyl-5-(methylthio)	14.012	0.52	14.293	0.94	11.548	0.03	14.576	2.20
5-Acetoxymethyl-2-furaldehyde	20.277	0.09	21.702	0.44	-	-	-	-
Monomethyl malonate	20.784	0.11	22.082	0.34	-	-	-	-
17-Pentatriacontene	33.204	0.06	-	-	-	-	-	-
Ethyl ester	37.252	5.76	37.325	0.40	37.108	3.48	-	-
Sucrose	29.674	0.13	29.674	0.13	25.247	0.14	-	-
Methyl glyoxal	-	-	3.192	0.14	4.540	1.28	4.509	2.42
Butyric acid	-	-	5.279	1.43	4.862	0.30	-	-
4-Penten-2-one, 4-methyl	-	-	5.416	0.86	5.612	1.25	6.250	0.79
1-Hepten-4-ol	-	-	7.975	0.07	-	-	-	-
2-Hexanone	-	-	9.137	0.15	-	-	-	-
1,3-Dioxane, 2-ethyl-5-methyl-	-	-	10.538	0.66	12.394	1.22	-	-
Oxirane, 2,2-dimethyl-3-propyl	-	-	16.080	0.07	14.391	0.16	-	-
2-Butanone	-	-	18.634	0.28	17.584	0.08	27.867	0.03
Catechol	-	-	19.113	0.52	-	-	-	-
2,3-Dimethyldecane	-	-	28.913	0.07	27.867	0.03	-	-
2,3-Epoxybutane	-	-	35.661	0.39	37.227	4.75	37.325	0.40

RT: Retention Time (Minutes) PA: Peak Area (%)

The results further showed that during dehydration of mango slices of Fajri variety, Cyclobutanemethanol, N-Methoxymethyl and Methylnonanoic acid compounds were found to be highly sensitive and were not detected in dehydrated products. The compound, 2-Pyrolidinone was stable up to 50 °C while 1,4-

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Butanediol, 2-Chlorophenol, and Sucrose were found to be stable up to 60 °C. None of the flavoring/volatile compounds were found to be stable at 70 °C in case of Fajri variety. Similarly, Dimethyl ether, Acetic acid, Hexyne, 5-methyl, Butyrolactone, Dihydroxyacetone, 3-Methoxy-3-methylbutanol and Hexadecyl propyl ether were not detected in fresh fruit but were detected in dehydrated slices of mango in Fajri variety (Table 5).

Table-5. Volatile compounds of Fajri variety.

Compound	Fresh Fruit (raw)		Dehydration Temperature					
			50°C		60°C		70°C	
	RT	PA	RT	PA	RT	PA	RT	PA
1,4-Butanediol	4.153	9.41	4.721	1.09	4.462	0.45	-	-
2-Pyrolidinone	8.789	2.46	5.287	0.76	-	-	-	-
Cyclobutanemethanol	12.332	1.51	-	-	-	-	-	-
2-Chlorophenol	14.227	3.32	15.994	0.07	14.464	0.12	-	-
Thiophene	20.941	0.04	-	-	-	-	18.445	0.28
N-Methoxymethyl	33.923	0.15	-	-	-	-	-	-
Methylnonanoic acid	37.323	0.41	-	-	-	-	-	-
Sucrose	29.674	0.13	29.674	0.13	25.247	0.14		
Dimethyl ether	-	-	3.290	0.81	3.816	1.50	3.198	2.15
Acetic acid	-	-	3.396	0.07	-	-	-	-
Hexyne, 5-methyl	-	-	6.960	1.78	5.148	1.65	5.523	0.81
Butyrolactone	-	-	7.306	1.01	-	-	7.675	0.40
Dihydroxyacetone	-	-	9.007	0.10	8.982	1.63	-	-
3-Methoxy-3-methylbutanol	-	-	30.311	0.07	33.977	0.13	36.453	0.09
Hexadecyl propyl ether	-	-	33.218	0.06	35.149	0.01	37.227	0.52

RT: Retention Time (Minutes) PA: Peak Area (%)

Among these volatile compounds, 2-Furanmethanol, Furan, 2-methyl-5-(methylthio), Furanmethanol, 3-Furaldehyde, 2-Propanone, Hydroxy dimethylprop-2, 2-Pyrolidinone, 3-Amino-2-oxazolidinone, Dihydroxyacetic acid, Ethyl ester, Glyoxal, Methylnonanoic acid, N-Methoxymethyl, 17-Pentatriacontene, n-Hexadecanoic acid, Methyl glyoxal, 2,5-Furandione, 2-Chloro-1-propanol, Methyl glyoxal, Melezitose, Cyclopentanol, Butyric acid, 4-Penten-2-one, 4-methyl, 1-Hepten-4-ol, 1,3-Dioxane, 2-ethyl-5-methyl, 2-Hexanone, Oxirane, 2,2-dimethyl-3-propyl, 2-Butanone, Butyrolactone, 2,3-Dimethyldecane and Sucrose were members of the aromatic compounds contributing specific flavor. The rest of the volatile compounds detected during study were from the group of chemicals used as Agrochemical, fuel, fungicide, allergen, humectant, fuel residues, byproducts of thermal processing, intermediate products, poultry medicine and plant growth promotors etc. Most of the flavoring compounds detected after dehydration were from secondary metabolites which might be less quantity in fresh mango but were detected after removal of water due to concentration factor.

Discussion

The current research was carried out to investigate the nutritional status of major mango varieties of Pakistan. For the purpose, Chaunsa, Sindhri and Fajri varieties were selected and subjected to chemical analysis. The results indicated that the moisture contents were ranged from 78.78±0.15% to 79.62±0.27% in these varieties. The results were in line with the findings of Dereje and Abera, (2020), who also reported 78-80% moisture in mango pulp while working on dehydration of the fruit. The results are also closely related to the finding of Naz et al. (2014) who found 81.40%, 82.70% and 81.85% moisture in Sindhri, Chaunsa and Fajri variety, respectively. The slight differences in the moisture contents might be due to variation in agricultural practices (like soil management,

irrigation, fertilizer, etc.) and environmental factors as also reported by Lechaudel and Joas (2007) who recommended that the quality of mango fruits is influenced by environmental factors including light, temperature, carbon availability etc. Many other scientists (Maldonado-Celis et al., 2019; Farina et al., 2020; Minuye et al., 2024) also observed similar results for moisture contents of the mango pulp while working on phytochemical composition of mangoes.

In Chaunsa, Sindhri and Fajri varieties the ash contents were ranged from 0.35% to 0.48% and minerals were ranged from 0.73±0.01mg/100g to 1579±2.65 mg/100g with potassium as the dominating mineral followed by magnesium. Among varieties, the mineral contents were found to be significantly higher in Sindhri variety. The minerals detected in the mango pulp were potassium, magnesium, calcium, iron and zinc (as per descending order with respect to concentrations). The results are justified by the findings of Maldonado-Celis et al. (2019) and Farina et al. (2020) who also detected/measured the same minerals in mango with varying concentrations. Fat contents ranged between 0.41 to 0.55% in Sindhri, Chaunsa and Fajri variety. The results were found to in line with those of Naz et al. (2014) who also reported similar compositional analysis of the mango varieties. According to Minuye et al. (2024), mangoes contain total phenolics contents ranged from 92.44 to 141.78 mg/100g. They reported while working on nutritional and antioxidant properties of mangoes. The same range of total phenolics (116.67 to 175.00 mg/100g) was found in the current study. So, the current research results of total phenolics are justifiable with the results of Minuye et al. (2024).

Antioxidants (DPPH) results of current research work were found in the range of 72 to 77% in fresh mango pulp. The current research findings are similar to those of Ahmad et al. (2024). They also found the DPPH value of fresh mangoes varies from 65 to 70% when they were working on the effect of pretreatment on nutritional composition of the mango to produce dehydrated fruit. Similarly, according to Mongi (2023), microbial load in fresh mango pulp was ranged between 3.9-4.2 log10 cfu/g which justifies the results of the current research work (with average bacterial load of 4.13-4.20 log10 cfu/g).

The color (L*, a* and b*) values of present study are in line with the results of Dereje and Abera (2020) also found color values of fresh mango L* (58.76), a* (12.31) and b* (52.65) in their study when they were working on the quality of dried mangoes. All the volatile compounds are not the contributor of aroma and flavor in mango. Whether the unique or high content volatile compound contributes the overall flavors in mango. GC detection method was used to check the flavor distribution based on aromatic substance intensity because of effective and less time-consuming method. Organic acids, aldehydes, alcohols, ketones, terpenes, and esters were found in the raw varieties of mango. These volatile compounds might contribute to the flavor and overall aroma of mango as also described by Pino et al. (2005) and Haocheng et al. (2020). They suggested that alcohols, ketones, terpenes and aldehydes play a significant role in the special flavor of mango.

According to the study, terpenes and aldehydes play a significant role in the special flavor of mango. So, the results were found similar with the findings of (Haocheng et al., 2020) who also reported that terpenes and aldehydes are special flavors of mango. El-Hadi et al. (2013) and Shi et al. (2025) also suggested that the volatile compounds in fruits are basically esters of chemical groups like ketones, terpenoids, lactones, apocarotenoids, alcohols and ketones, these reports also support the outcomes of current research work. A higher concentration of volatile compounds was found in Chaunsa and Sindhri as compared to Fajri variety. This might be due to specific genetic makeup of the varieties as variation in flavoring compounds in varieties is directly linked with genetic makeup, maturity level, climacteric conditions and agro practices (El-Hadi et al., 2013).

The drying temperature significantly affected the volatile compounds and organic acids. Some compounds were highly heat sensitive and degraded with high temperature while some others showed stability. This alteration in flavor profile of mango varieties can be justified by the findings of Silva et al. (2021) and Bonneau et al. (2018) who also suggested that the industrial processing and high temperature causes reduction in volatile compounds in the food commodities. Wang et al. (2024) reported the conversion of volatile organic compounds into other by-products due to high temperature. The detection of new volatile compounds in mango slices due to drying temperature might be due to conversion of existing aromatic groups into other relatively stable compounds. The results are in line with a number of previous studies. Aboshi et al. (2020) observed changes in volatile flavoring compounds of watermelon juice and reported that there was reduction in ketone, aldehyde and alcohol based volatile

compounds while dimethylsulfide and methional were increased due to high temperature. The modification in flavoring profile of the varieties might be due to oxidation, reduction, acylation or it might be due to methylation and closure of the cyclic ring either due to relatively elevated temperature or due to postharvest ripening mechanisms (El-Hadi et al., 2013). Wongkaew et al. (2021) also reported alteration in terpene hydrocarbons and oxygenated sesquiterpenoids in mango varieties due to heat treatment. The differences in changes in flavoring compounds within varieties might be due to interaction with other compounds. The results are in line with Wongkaew et al. (2021) who also found that the changes in aromatic compounds in mango varieties subjected to heat treatment were variety dependent. Based on these results, it was concluded that, there was a significant variation in the chemical composition of the mango from different varieties cultivated in the South Punjab region of Pakistan. Each variety had its own specific parameters like Sindhri variety was found to be good with respect to ash and mineral contents. Whereas the Chaunsa variety was better with respect to phytochemicals and flavoring compounds. Similarly, the drying/dehydration temperature affected some quality parameters like flavoring compounds, protein, fat and color. However, keeping in view all the parameters, the drying temperature up to 60 °C was considered to be acceptable for the production of dehydrated/dried mango slices.

Conclusion

Based on current research work, it was concluded that, there was a significant variation in the chemical composition of the mango from different varieties cultivated in the South Punjab region of Pakistan. Each variety had its own specific parameters like Sindhri variety was found to be good with respect to ash and mineral contents. Whereas the Chaunsa variety was better with respect to phytochemicals and flavoring compounds. Sindhri exhibited higher ash (0.48±0.01%) and mineral content, while Chaunsa showed superior phytochemical and flavor profiles with 175.00±1.73 mg GAE/100g of total phenolic contents and 77.67±0.33% antioxidant activity. Identified volatile compounds included aldehydes, ketones, terpenes, alcohols, and esters, contributing to mango's characteristic aroma. Major compounds detected were acetic acid, butanone, furanmethanol, and glyceraldehyde. Butane derivatives varied across varieties, including butanediol (Fajri), butyrolactone (Chaunsa), and 1-butanol (Chaunsa and Sindhri). It was further concluded that in case of mango dehydration through hot air oven/dehydrator, the drying temperature up to 60 °C could be suitable for the production of dehydrated mango slices in order to retain reasonable flavoring compounds and consumer acceptability of the dehydrated mango slices. The temperature, above 60 °C resulted in substantial modifications in the volatile/flavoring compounds. However, based on current research outcomes, it is hereby suggested that there is a need for exploration of impact of different packaging materials on the shelf stability of the slices. More research is required to address the issues of browning, over drying during storage, more flavor retention and mechanization of processing technology.

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Contribution of Authors

Hayat K: Conceived idea, designed research methodology, collected & analysed data and wrote the first draft of the manuscript
Farooq U: Interpreted data, edited manuscript and supervised the study
Shafi A & Khan Z: Helped and guided in research methodology, data analysis and manuscript write-up.

All authors read and approved the final draft of the manuscript.

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