Journal of Spices and Aromatic Crops
Vol. 33 (1): 23-36 (2024)
10.25081/josac.2024.v33.i1.9144

Indian Society for Spices

Studies on quality of turmeric powder influenced by pre–treatments of fresh sliced rhizomes

S S Tule[1], J H Kadam[1*], G D Shirke[1], S D Pujari[1] & R B Wagh[2]

[1.] *Department of Post–harvest management of Medicinal, Aromatic, Plantation, Spices and Forest crops, Dr. Balasaheb Sawant Konkan Krishi Vidyapith Dapoli, Maharashtra, India*
[2.] *Sher–e–Kashmir University of Agriculture Sciences and Technology, Srinagar*
**Email: jhkadammpkv@gmail.com*

Received 27 May 2024; Revised 23 June 2024; Accepted 30 June 2024

Abstract

The curcumin is an active component of turmeric which is highly valued and ingredient of many traditional herbal medicines. The objective of the present experiment was to retain the curcumin in turmeric powder and to improve the quality of turmeric powder. The experiment was laid out in Completely Randomized Design (CRD) with ten different treatments. An attempt was made to to address the concerns about reduction in curcumin content due to the traditional curing and processing methods and to prepare high quality turmeric powder by assessing the effect of various pre–treatments on the chemical and physical parameters. The results indicated that blanching of turmeric rhizomes at 90ºC ±2ºC for 5 minutes significantly impacts the physical, chemical, and sensory properties of the turmeric powder. The beneficial compounds like curcumin, polyphenols, flavonoids, alkaloids, tannins, oleoresins and essential oil in blanched rhizomes was retained in turmeric powder which helps in optimizing the nutritional and medicinal value of turmeric.

Keywords: Turmeric, secondary metabolites, pre–treatments, curcumin, essential oils, oleoresin

Introduction

The turmeric, popularly known as golden spice, is the rhizome of the *Curcuma longa*, a member of the zingiberaceae family. Most of the turmeric used, produced, and exported worldwide originates in India. It accounts for 80% of global production and 60% of global exports (Anonymous, 2022a). India is the leading producer of turmeric and it is cultivated in Maharashtra, Telangana, Karnataka, Tamil Nadu, Andhra Pradesh, West Bengal, Orissa, Kerala, Assam, Gujarat and Haryana. In Maharashtra turmeric is grown in 60,840 hectares, with an annual production of 12,16,975 tonnes (Anonymous, 2022b). It is Mostly used as a spice in Indian cooking. It has many health benefits. (Luthra *et al*. 2001). Its unique flavour and its nutritional and therapeutic qualities made it popular even in Vedic times. In addition, turmeric also finds uses across cultural, religious, and wellness applications (Sanchavat *et al.* 2012). Apart from its use as a dye and ingredient in cosmetic products, turmeric and its extracts are used as an insect repellent also. Turmeric is used as a natural remedy for rheumatoid arthritis, chronic anterior uveitis, conjunctivitis, skin cancer, chicken pox, smallpox, wound healing, urinary tract infections, and liver disorders (Dixit *et al.* 1988). It is also used to treat dyspeptic symptoms, such as loss of appetite and postprandial fullness, as well as colic, digestive problems, flatulence, jaundice, and irregular menstruation (Bundy *et al.* 2004). Turmeric has been used for millennia as an antibiotic, blood purifier, dermatological therapy, conjunctivitis treatment, liver disease management, antioxidant, and cholesterol control agent (Rathaur *et al.* 2012). Turmeric's natural food colouring properties stem from its natural components, which has led to a rise in the market demand for it as a food additive (Pari *et al.* 2008).

Traditionally, turmeric powder is prepared by curing, drying, polishing, and pulverizing. However, during curing the curcumin content and other secondary metabolites are lost in the finished products as compared to the fresh turmeric rhizomes. It is also noticed that the turmeric powder is adulterated with other compounds. Presently, the consumers prefer to prepare turmeric powder themselves for domestic use. The preparation of dried turmeric slices preserves its natural content but become black due to enzymatic activity. Hence, pretreatment with antioxidants like ascorbic acid, citric acid, sodium chloride and chitosan are done to reduce enzymatic activity during blanching. It helps to improve quality of turmeric powder with its natural content and helps to extend shelf life of turmeric slices. The prepared dried slices are known as flakes and flakes can be ground into fine powder at home scale.

Materials and methods

The experiment was laid out in Completely Randomized Design (CRD) with ten different treatments viz. control – slicing of fresh rhizomes (T1), traditional method – Curing and drying (T2) and eight treatments involving blanching in water (T3), water + 0.1 % ascorbic acid (T4), water + 2 % citric acid (T5), water + 3 % sodium chloride (T6), water + 0.5 % chitosan (T7), water + 1 % chitosan (T8), water + 1.5 % chitosan (T9), water + 2 % chitosan (T10) at 90°C±2°C for 5 min. Three replicates were maintained for each treatment.

The fresh turmeric rhizomes of variety Salem were collected from the field. These rhizomes were washed with water followed by cleaning. Cleaned rhizomes (2 kg for each treatment) were blanched for 5 min at 90°C±2°C in water as per treatment using muslin cloth. Further, the blanched rhizomes were sliced to 1 to 2 mm thickness. From the 2 kg cleaned rhizomes, 1.8 kg slices were obtained. These slices were further shade dried at room temperature. The dried turmeric flakes were powdered and packed using low density polyethylene (LDPE).

The various physical parameters were recorded *viz.,* fresh weight of rhizomes (Asafa and Akanbi, 2018), fresh and dry weight of rhizome slices (Govindarajan and Stahl, 1980). Colour (L* a*and b* value) of slices was measured with the colorimeter (Model CR–400/410 chromameter, Konica Minolta Holdings Inc., Tokyo, Japan) and result was expressed in accordance with the CIE lab system (Hutchings) with reference to illuminant D65 and a viewing angle of 10 degree. The L*, a*, b* values were measured as per Madhusankha (2018). The texture in terms of crispiness value of turmeric dried slices was determined with method suggested by Chen *et al*. (2005) and the hardness value of turmeric dried slices was determined as per Saha *et al*. (2022).

Chemical parameters

Curcumin (%)

Acetone was used for curcumin extraction. The curcumin in the samples was estimated as per Geethanjali *et al.* (2016).

$$\text{Curcumin (\%)} = \text{Ds} \times \frac{\text{As}}{100} \times \text{W} \times 1650\text{X}100$$

where, Ds – dilution volume of the sample; Ws –weight of the sample (g); As – absorbance of the sample; 1650 – calculated standard value.

Determination of antioxidant activity

Methanolic extract of the sample was prepared and using the technique suggested by Boix *et al*., (2011) and the antioxidant activity of the plant extract against DPPH was ascertained. The antioxidant activity was expressed as quercetin equivalents per milligram dry weight.

Flavonoid (%): Flavonoid content was estimated by aluminium chloride colorimetric technique as described by Zhishen *et al*. (1999) using 0.01–1.0 mg/ml of rutin as calibration standard.

Alkaloid (%): Alkaloid content was estimated by spectrophotometric method as described by (Shamsa *et al.* 2008) using bromocresol green (BCG) solution.

Polyphenol (%): Following the method of Ainsworth *et al*. (2007), the total phenol content (TPC) of the turmeric stalk and fingers was estimated spectrophotometrically using the Folin–Ciocalteu colorimetric method. Gallic acid was used as the reference, and the results were expressed as gallic acid equivalent (GAE) per gram of sample.

Tannin (%): Tannin content was estimated by spectrophotometric method as described by Polshettiwar *et al*. (2007) using 0.5 ml of Folin–Denis reagent.

Saponin (%): After drying the turmeric slices, saponins were extracted using Obadoni and Ochuko's (2002) method.

Terpenoid (%): The terpenoid content was estimated using the technique described by Das *et al.* (2022) using 200 mg of polyvinylpolypyrrolidone (PVPP).

Essential oil (%): Essential oil was extracted using hydrodistillation method as suggested by Ching *et al.* (2014).

$$\text{Essential oil}(\%) = \frac{\text{Volume of oil obtained (ml)}}{\text{Weight of sample taken (g)}} \times 100$$

Oleoresin (%): To get a consistent particle size of 0.42 mm, the dried turmeric slices were ground into a powder and then passed through a 40 mesh screen. Ethanol was used for oleoresin extraction. The yield of the oleoresin was expressed as percent w/w of dried rhizome powder (Vijayan *et al*., 2021).

Results and discussion

Physical parameters

Dry weight of slices (g)

Blanching in water produced the highest average dry weight of the slices which was at par with control. (Table 1). Blanching aids in the deactivation of enzymes and gelatinization of starch. Boiling rhizomes accelerates the rate of drying, allows uniform drying, and encourages the gelatinization of starch. Findings of Govindarajan and Stahl (1980) in turmeric supports the above results.

Colour L* a* b* value

Using colour coordinates (L* a* b* values), the hue of dried turmeric slices was noted where L* stands for lightness, a* for redness, and b* for yellowness in turmeric. It was noted that the control (without blanching) had the lowest L* value (darkness to lightness), whereas the blanching in water along with 0.1 % ascorbic acid recorded the maximum L* value (Table 1) which was at par with blanching in water. The control treatment yielded the maximum a* (greenness to redness) value. In contrast, the lowest a* value was noted during blanching in water. The blanching in water yielded the highest b* (blueness to yellowness) value, whereas the control (without blanching) had the lowest b* value. Blanching the rhizomes may aid in the release of curcumin from the cells, giving a brighter colour and redder hue. When dried in the shade, the hue angle peaked throughout the drying period and then progressively decreased until the process was completed. On the other hand, in other characteristics like the overall colour shift, sun drying showed a persistent downward tendency; however, the colour was retained during the blanching process. Additionally, it was noted that the dried finger's L*, a*, and b* values were lower than those of the fresh samples; the sun–dried samples had much lower b* and L* values. The dried samples from the blanching treatment were still slightly yellower compared to those from other treatments, particularly on the underside of the slice due to increased degradation of curcumin. Similar results were reported by Mahayotheea (2020) in cassumunar ginger (*Zingiber montanum*) that the drying temperature of blanched samples significantly affect the color parameters**.**

Crispiness

The blanching of turmeric rhizomes in water yielded significantly highest crispiness, whereas the traditional curing produced the lowest. Crushing strength was used to examine the texture of dried turmeric slices from all pre–treatments. The blanching in water required the greatest amount of power which indicates it was crispier. According to Saha *et al.* (2022), crushing sliced sun–dried turmeric required a maximum peak force of 45.40 kg, whereas boiling entire turmeric dried in the sun required the least amount of force (29.71 kg). George (2015) reported similar outcome for jackfruit chips.

Hardness

The hardness value was significantly lowest in blanching with water and highest in traditional curing. The least crispy product was indicated by the greater hardness value. The amount of moisture removed from the cell determines the hardness value. In contrast to other pre–treatments, blanching allows the skin's microspores to extract moisture from the skin more quickly, making the slices more delicate. According to Saha *et al.* (2022), the pre–treatments of fried jackfruit chips had hardness values of 1.24 N, 1.24 N and 2.99 N, 1.78 N for the 0^{th} and 90^{th} days of storage in laminated aluminium pouches and low–density polythene, respectively. The same phenomena was observed by Molla and Nasrin (2008) in jackfruit chips.

Chemical parameters

Curcumin (%)

Blanching in water for five minutes retained significantly highest mean curcumin, whereas the control showed the lowest (Table 2). Turmeric rhizomes contain a brilliant yellow phenolic chemical called curcumin, which aids in controlling oxidation throughout the plant's growth. This significant component is crucial in determining the quality of turmeric. Curcumin benefits from blanching because it becomes more stable and bioavailable. The raw material is submerged for a limited period of time in steam or boiling water, which helps to inactivate enzymes and lower the microbial load. This procedure might improve curcumin's retention throughout further processing and stop it from degrading. Additionally, blanching can contribute to increased solubility and bio accessibility of curcumin, potentially improving its absorption and therapeutic efficiency upon consumption. Similar results were reported by Saha *et al.* (2022), Hazra *et al.* (2015) and Jadhav *et. al.* (2023) in turmeric.

Antioxidant (%)

Blanching in chitosan (2%) resulted in significantly higher antioxidant activity than that of the control (Table 2). The heat treatment during blanching might improve the extractability (via matrix softening) of phytochemicals linked with antioxidant.

Table 1. Effect of different treatments on physical parameters of the fresh rhizome slices of turmeric

Treatment	Dry wt. of slices (g)	Colour L* a* b* values			Texture	
		L*	a*	b*	Crispiness (dB)	Hardness (N)
T1	474.38	31.46	26.96	36.63	44.30	18.17
T2	428.52	36.31	22.23	44.53	41.64	20.81
T3	478.28	57.03	17.71	60.56	46.87	6.78
T4	469.25	58.56	20.57	54.58	45.17	7.27
T5	469.25	45.50	22.94	41.83	45.47	8.09
T6	459.36	53.84	19.68	40.71	42.76	15.64
T7	471.40	46.43	21.40	51.86	42.43	10.90
T8	466.29	38.72	21.32	44.23	43.87	9.89
T9	446.07	43.83	18.44	47.38	41.96	8.68
T10	444.86	38.87	21.80	47.54	43.51	8.05
Mean	460.77	45.06	21.31	46.99	43.80	11.43
SEm±	1.62	2.64	1.24	2.75	0.40	0.15
CD 5%	4.77	7.78	3.67	8.11	1.18	0.43
CV	3.37	2.37	2.34	2.35	4.07	3.52

Activity which may result in the variability in antioxidant activity. Heat treatments have the potential to alter the structure and/or polymerize phytochemicals, resulting in the formation of new compounds that possess distinct antioxidant properties compared to their parent compounds. Green leafy vegetables had a similar outcome (Adefegha and Oboh, 2011). The encouraging outcome was observed in artichokes (*C. scolymus* L.) by Ferracane *et al.* (2008). As an edible coating material, chitosan has been reported to be highly effective in extending the postharvest life of many crops while reducing moisture loss, respiration, ethylene production, ripening, softening, controlling the decay, and maintaining fruit quality, along with storability. The application of the chitosan coating significantly increased the antioxidant capacity of the turmeric, indicating that the antioxidant effects of chitosan was great enough to significantly alter the characteristics of turmeric.

Flavonoid (%)

In the treatment blanching in water, the mean flavonoid content was significantly higher as compared to other treatments. This demonstrates that blanching fresh rhizomes for five minutes at 90°C in hot water can raise the amounts of condensed tannin, total phenolics and flavonoids. On the other hand, the system's antioxidants may oxidise more quickly due to the high heat treatment. Pujimulyani *et al.* (2018) reported a similar outcome in *Curcuma aeruginosa*. Chitosan has capacity to activate phenylalanine ammonia–lyase and tyrosine ammonia–lyase. The two enzymes involved in the synthesis of these chemicals, may help to explain the elevated levels of total phenolic and flavonoid contents in chitosan–coated samples. Similar result was observed by Khan *et al.* (2003) in soybean leaves.

Alkaloid (%)

The mean alkaloid content was higher in blanching in water which was at par with blanching in water with 0.1 % ascorbic acid while lowest content was recorded in the control. The impact of blanching on the amount of alkaloids present in plants and their products is debatable and equivocal. Nonetheless, this investigation revealed a rise in the alkaloids present in turmeric with blanching. Even while this seemed confusing, the likely cause could be the turmeric's increased alkaloids synthesis brought on by the lowering heat during blanching. This is in line with Tesleem *et al.* (2009) study on *Talinum triagulare* leaves, wherein blanched vegetables had a higher alkaloids content than sun–dried vegetables. Oyenka and Nwambekwe (2007) reported decrease in alkaloids content of vegetables with boiling. Additionally, Ebuehi *et al.* (2005) reported on the relative stability of alkaloids when food is blanched in the case of cassava (*Manihot esculenta* L.) tubers and leaves. Fruit and vegetable coatings made of chitosan create a semipermeable layer on their surface that delays respiration, reduces weight loss, preserves quality, and extends shelf life. The various concentrations of chitosan affect the accumulation of alkaloids in turmeric. The alkaloids in turmeric slices increased with varying chitosan concentrations. The abiotic elicitors, such as chitosan, raise the concentrations of tropane alkaloids in ginger, and scopolamine and hyoscyamine in *Brugmansia candida* (Hashimoto *et al.*, 1993).

Polyphenols (%)

The treatment blanching in water recorded the highest mean polyphenol content while the lowest was recorded in control. This result is comparable to that of İzli (2017) in kiwi, who discovered that kiwi dates had the highest phenolic content when high temperatures were applied. Chitosan coating plays a significant role in fruit and vegetable preservation as explained earlier. The polyphenol contents are protected by the applications of L–ascorbic acid, low–methoxy pectin, and sucrose. A supporting finding suggested that they were more effective when combined, as demonstrated by studies on strawberries by Garrote and Bertone (1989) and Kmiecik *et al.* (2000).

Tannin (%)

The treatment blanching in water recorded significantly higher tannin concentration than control. The observed elevation in tannin level is consistent with several studies that show the influence of temperature on turmeric's tannin content. The rise may have resulted from the high temperature's effect on the hydrogen bonds that connect tannin complexes, raising the concentration of free tannins. It has been demonstrated that the majority of the tannins found in fresh vegetables were attached to other substances, such as carbohydrates, proteins, and other molecules. Oboh and Akindahunsi (2004) discovered a similar outcome in green leafy vegetables, and Lee and Lee (2012) in persimmon fruit. Peng and Jiang (2004) reported the encouraging outcome in fresh–cut Chinese water chestnut. Turmeric rhizomes that were blanched in chitosan before drying had higher tannin content than the dried slices that weren't coated. It is most likely caused by tannins' oxidation and oxygen exposure. Connor *et al.* (2002) reported a similar outcome in blueberries.

Saponins (%)

The control had the highest saponin content, whereas the 0.5% chitosan blanching treatment showed the lowest saponin content. It was hypothesised that saponins would diminish during blanching with water at high temperatures. It is noted that the saponins are temperature–sensitive. Tan *et al.* (2014) reported a similar outcome in bitter melon, stating that heat treatment above 40°C will reduce the overall saponin level but no particular saponin components were found. Donya *et al.* (2007) reported that saponin was absent in blanched bitter gourds.

Terpenoid (%)

The treatment blanching in water reported the highest mean terpenoid whereas it was lowest in the control. Terpenoids are essential for the growth and development of plants as well as for physiological functions and environmental adaptation. For pepper that has been thermally treated, the rise in terpenoids may be due to the increased temperature. Treatments of green vegetables at high temperatures and high pressures led to an increase in the breakdown of terpenoids. It is evident that blanching needs to be done at the right temperatures and for the right amount of time. Kebede *et al. (2013)* also reported encouraging outcome in green veggies.

Essential oil

The treatment blanching in water reported the highest mean essential oil and lowest in the control. Essential oils play a crucial role in mitigating abiotic stress, providing protection against predators and pests, and attracting pollinators. The presence of low boiling and less volatile non–oxygenated terpene hydrocarbons, which may not be lost easily under strong blanching treatment, and the callous nature of the herb with a hard rhizome may be the reasons for the lesser losses in blanched turmeric. Koller (1993) reported similar outcome in *Rosmarinus officinalis*.

Table 2. Effect of different treatments on chemical parameters of turmeric slices of fresh rhizomes (in %)

Treatment	Curcumin	Antioxidant	Flavonoid	Alkaloid	Polyphenol	Tannin	Saponin	Terpenoid	Essential oil	Oleoresin
T1	2.03	64.15	0.31	0.34	0.41	0.54	0.59	0.60	2.25	8.16
T2	2.12	65.15	0.34	0.35	0.43	0.55	0.31	0.62	2.27	8.20
T3	3.72	65.36	0.62	0.67	0.49	0.91	0.55	0.98	3.93	9.87
T4	3.17	68.44	0.51	0.63	0.47	0.86	0.48	0.90	3.61	9.76
T5	2.98	67.72	0.49	0.56	0.46	0.84	0.46	0.88	2.47	9.70
T6	2.82	67.59	0.54	0.54	0.46	0.74	0.33	0.78	2.40	9.68
T7	2.08	67.52	0.44	0.41	0.42	0.63	0.29	0.72	2.36	8.23
T8	2.35	67.70	0.47	0.46	0.43	0.77	0.37	0.75	2.29	8.79
T9	3.05	68.41	0.48	0.53	0.44	0.85	0.39	0.76	2.37	8.87
T10	3.08	68.96	0.52	0.61	0.45	0.89	0.42	0.81	2.49	9.23
Mean	2.74	67.10	0.47	0.51	0.45	0.76	0.42	0.78	2.64	9.05
SEm±	0.16	0.01	0.03	0.03	0.01	0.01	0.03	0.05	0.16	0.01
CD 5%	0.49	0.04	0.08	0.09	0.03	0.04	0.07	0.14	0.47	0.03
CV	2.87	3.26	1.37	3.38	2.35	4.36	2.39	2.35	1.38	3.88

Oleoresin (%)

The blanching in water had the highest oleoresin, whereas the lowest was observed in control. Through the deactivation of enzymes involved in degradation, the blanching process can affect the content of oleoresins. This keeps the oleoresins intact and keeps them from losing their taste or scent. Out of all the pre–treatments, the turmeric that was blanched produced the highest amount of oleoresins, indicating that a high–quality powdered product was achieved. But the precise result can change based on things like blanching in various substances. According to Jayashree and Zachariah (2012), whole cooked turmeric had a greater oleoresin concentration than sliced turmeric. Nithya (2020) also found that boiled samples had the highest oleoresin content in turmeric. Padma *et al.* (2016) in observed that the oleoresin content obtained from boiled turmeric rhizomes following all the drying methods was higher.

In conclusion, the pre–treatment of blanching (90oC ± 2oC) for 5 min followed by slicing and drying of rhizomes recorded better physico–chemical properties such as curcumin, anti–oxidant, tannin, terpenoid, essential oil and oleoresin among all treatments. The blanching treatment retains color, enhance flavor of slices and improves quality of turmeric powder. Hence, it is concluded that blanching the fresh rhizomes in hot water (90oC ± 2oC) for 5 min is ideal to prepare good quality turmeric dry flakes.

References

Adefegha S A & Oboh G 2011 Enhancement of total phenolics and antioxidant properties of some tropical green leafy vegetables by steam cooking. Journal of Food Processing and Preservation. 35: 615–622. https://doi.org/10.1111/j.1745–4549.2010.00509.x.

Ainsworth E A & Gillespie K M 2007 Estimation of total phenolic content and other oxidation substrates in plant tissues using Folin–Ciocalteu reagent, Nature protocols. 2(4): 875–877. DOI: 10.1038/nprot.2007.102 Corpus ID: 8924784.

Anonymous, 2022a. Turmeric Outlook – May 2020. https://bit.ly/3l3sms7.

Anonymous, 2022b. Spices growing states, countries, and statistics. http://www.indianspices.com.

Asafa R F & Akanbi W B 2018 Growth and rhizome yield of Ginger (*Zingiber officinale* L.) as influenced by propagule size and nitrogen levels in Ogbomoso, Southwestern Nigeria. International Letters of Natural Sciences. 67: 60–64. https://api.semanticscholar. org/CorpusID:56079676.

Boix A, Thompson S, Stark M, Ou Z Q & Gould K S 2011 Antioxidant activity of puha (*Sonchus oleraceus* L.) as assessed by the cellular antioxidant activity (CAA) assay. Phytotherapy Research. 25(12): 1876-1882. DOI: 10.1002/ptr.364.

Bundy R, Walker A F, Middleton R & Booth J 2004 Turmeric extract may improve irritable bowel syndrome symptomology in otherwise healthy adults: a pilot study. J. Altern. Complement. Med. 10(6): 1015–1018. DOI: 10.1089/acm.2004. 10.1015.

Chen J, Karlsson C & Povey M 2005 Acoustic envelope detector for crispness assessment of biscuits. J. Texture Stud. 36(2): 139-156. https://doi.org/10.1111/j. 1745–4603.2005.00008.

Ching W Y, Bin–Yusoff Y & Wan–Amarina WNB 2014 Extraction of essential oil from *Curcuma longa*. Journal of Food Chemistry and Nutrition. 2(1): 01–10. https://api.semantic scholar.org/Corpus ID:82856869.

Connor M, Luby A, Hanckok F J, Berkheimer S & Hanson J E 2002 Changes in fruit antioxidant activity among blueberry cultivars during cold temperature storage. J. Agric Food Chem. 50: 893-98. DOI: 10.1021/jf011212 y.

Das S, Goswami M, Yadav R N S & Bandyopadhyay T 2022 Quantitative estimation of terpenoid content in some tea cultivars of Northeast India and there in vitro cell cultures using an optimized spectophotometric method. J. Adv. Sci. Res. 13(03): 112–117. https://doi.org/10.55218/JASR.20221331 8.

Dixit V P, Jain P & Joshi S C 1988 Hypolipidaemic effects of *Curcuma longa* Linn., and Nardostachys jatamansi DC, in triton–induced hyperlipidaemic rats. Indian Journal of Physiology and Pharmacology, 32: 299–304.

Donya N, Hettiarachchy R, Liyanage J, Lay P, Chen & M Jalaluddin 2007 Effects of processing methods on the proximate composition and momordicosides K and L content of bitter melon vegetable, J. Agric. Food Chem. 55(14): 5827–5833. DOI: 10.1021/jf070428i.

Ebuehi O A T, Babalola O & Ahmed Z 2005 Phytochemical, nutritive and anti–nutritive composition of cassava (*Manihot esculenta* L) tubers and leaves; Nigerian Food Journal 23: 40–46. DOI:10.4314/nifoj.v23i1.33597.

Ferracane R, Pellegrini, N, Visconti A, Graziani G, Chiavaro E, Miglio C & Fogliano V 2008 Effects of different cooking methods on antioxidant profile, antioxidant capacity, a physical characteristic of artichoke. J. Agric. Food Chem. 56: 8601–8608. DOI: 10.1021/jf800408w.

Garrote R L & Bertone R A 1989 Osmotic concentration at low temperature of frozen strawberry halves. Effect of glycerol, glucose and sucrose solutions on exudate loss during thawing. Lebensmittel–Wissenschaft und–Technologie, 22: 264–267. https://api. semanticscholar.org/CorpusID:8955873 9.

Geethanjali A, Lalitha P and Jannathul M. 2016 Analysis of curcumin content of turmeric samples from various states of

India. Int. J. Pharma Chem Res. 2(1): 5–62.

George K 2015 Development and Evaluation of Vacuum Fried Jackfruit Chips (*Artocarpus heterophyllus*) Kelappaji college of agricultural engineering and technology, Tavanur Kerala, India. 679: 573.

Govindarajan, V. S. and Stahl, W. H. 1980. Turmeric chemistry, technology, and quality. Critical Reviews in Food Science & Nutrition, 12 (3): 199–301. DOI: 10.1080/104083980 09527278.

Hashimoto T, Yun D–J & Yamada Y 1993 Production of tropane alkaloids in genetically engineered root cultures. Phytochemistry 32: 713–718. https://doi.org/10.1016/S0031-9422(00)95159–8.

Hazra K, Kumar R, Sarkar B K Chowdary Y A Devgan M & Ramaiah M 2015 UV–visible spectrophotometric estimation of curcumin in nano formulation. Int. J. Pharmacognosy Pharm. 2(3): 127–130. DOI:10.13040/IJPSR.0975–8232.

Hoque M A, Bala B K, Hossain M A & Uddin M B 2013 Drying kinetics of ginger rhizome (Zingiber officinale). Bangladesh Journal of Agricultural Research. 38(2): 301–319. DOI:10.3329/BJAR.V38I2.15892.

Izli N 2017 Drying kinetics, colour, total phenolic content and antioxidant capacity properties of kiwi dried by different methods. Journal of Food Measurement and Characterization. 11: 64–74. https://doi.org/10.1007/s11694–016–9372–6.

Jadhav K, Kadam J, Shirke G & Dhumal R 2023 Potential harvest of secondary metabolites from turmeric (*Curcuma longa* L). The Pharma Innovation Journal. 12(5): 2705–2712.

Jayashree & Zachariah John 2012 Processing of turmeric (*Curcuma longa*) by different curing methods and its effect on quality, Indian J. Agric. Sci. 5: 696–698. DOI: 10.56093/ijas.v86i5.58358.

Kebede B T, Grauwet T, Tabilo–Munizaga G, Palmers S, Vervoort L & Hendrickx M 2013 Headspace components that discriminate between thermal and high–pressure high temperature treated green vegetables: identification and linkage to possible process–induced chemical changes. Food Chemistry. 141(3): 1603–1613. https://doi.org/10.1016/j.foodchem.2013.05.097.

Kmiecik W, Jaworska G & Lisiewska Z 2000 Effect of sucrose, L–ascorbic acid and pectin on the quality of frozen strawberries. Journal of Polish Agricultural Universities, Food Science and Technology. 3(2): http://www.ejpau.media.pl/volume3 /issue2/food/abs-01.html.

Koller W D 1993 Quality of herbs and spices. In: Trends in Food Science and Technology IFCON. Proceedings, 7–9th September, Mysore: pp454.

Lee Dong–Won & Lee Seung–Cheol 2012 Effect of heat treatment condition on the antioxidant and several physiological activities of non–astringent persimmon fruit juice. Food Science and Biotechnology. 21(3): 815–822. https://doi.org/10.1007/s10068–012–0105–2.

Luthra P M, Singh R & Chandra R 2001 Therapeutic uses of *Curcuma longa* (turmeric). Indian Journal of Clinical Biochemistry. 16(2): 153–160. Doi: 10.1007/BF02864854.

Madhusankha P 2018 Analysis of curcumin content in Sri Lankan and Indian turmeric rhizomes and investigating its impact on the colour. Int. J. Food Sci. Nutr. 3(4): 03–05.

Molla M & Nasrin N 2008 Preparation and packaging of jackfruit chips MN Islam, MAJ Bhuyan J. Sustain. Crop Prod. 3(6): 41-47. DOI:10.29321/MAJ.2020.000333.

Nithya C 2020 Effect of Slice Thickness, Boiling and Drying Methods on Curcumin, Oleoresin and Essential Oil Content of Ground Turmeric. Madras Agric. J. 107 (1–3): 88–91. doi:10.29321/MAJ 2020.000333.

Obadoni B O & Ochuko P O 2002 Phytochemical studies and comparative efficacy of the crude extracts of some haemostatic plants in Edo and Delta States of Nigeria. Global Journal of pure and applied sciences. 8(2): 203-208. DOI:10.4314/GJPAS.V8I2.16033.

Oboh G & Akindahunsi A 2004 Change in the ascorbic acid, total phenol and antioxidant activity of sun–dried commonly consumed green leafy vegetables in Nigeria. Nutrition and Health. 18(1): 29-36. https://doi.org/10.1177/026010600401800103.

Padma M, Reddy B S & Madhava M 2016 Evaluation of the quality parameters of the turmeric rhizomes dried on different floors and conditions. Int. J. Agric. Sci. 12: 302-308. DOI:10.15740/HAS/IJAS/12.2/302–308.

Pari L, Tewas D & Eckel J 2008 Role of curcumin in health and disease. Archives of physiology and biochemistry. 114(2): 127–149. DOI: 10.1080/13813450802033958.

Peng L & Jiang Y 2004 Effects of heat treatment on the quality of fresh–cut Chinese water chestnut. Int. J Food Sci. Tech; 39: 143-8. https://doi.org/10.1046/j.0950–5423.2003.00767.

Polshettiwar S A, Ganjiwale R O, Wadher S J & Yeole P G 2007 Spectrophotometric estimation of total tannins in some ayurvedic eye drops. Indian J. Pharm. Sci. 69(4): 574. DOI:10.4103/0250–474X.36949.

Pujimulyanil D 2018 The Effects of Media and Blanching Time on the Antioxidative Properties of *Curcuma aeruginosa* Roxb. Indonesian J. Pharm. 32(2): 244-250. DOI: https://doi.org/10.22146/ijp.3634.

Ranganna S 1986 Handbook of analysis and quality control for fruit and vegetable products. Tata McGraw–Hill Education.

Rathaur P, Raja W, Ramteke P W & John S A 2012 Turmeric: The golden spice of life. Int. J. Pharm. Sci. Res. 3(7): 1987. DOI: 10.1201/9781420006322–7.

Saha G, Sharangi A B, Upadhyay K, Ahmed L, Alshammari N, Alabdallah N M & Saeed M 2022 Dynamics of drying turmeric rhizomes (*Curcuma longa* L.) with respect to its moisture, color, texture and quality, Agronomy. 12: 1420. https://doi.org/10.3390/agronomy 12061420.

Sanchavat H, Kothari S, Sharma D, Jain N K & Sharma G P 2012 Performance and economic evaluation of biomass and solar energy system for turmeric processing. Indian Journal of Hill Farming. 25(2): 1-5. https://api.semantic scholar.org/CorpusID:55705015.

Shamsa F, Monsef H, Ghamooshi R & Verdian–rizi M 2008 Spectrophotometric determination of total alkaloids in some Iranian medicinal plants. Thai J Pharm Sci. 32: 17–20. https://doi.org/10.56808/3027–7922.2196.

Tan S P, Vuong Q V, Stathopoulos C E, Parks S E & Roach P D 2014 Optimized aqueous extraction of saponins from bitter melon for production of a saponin–enriched bitter melon powder, J. Food Sci. 79 (7): E1372–E1381. https://doi.org/10.1111/1750–3841.12514.

Vijayan U K, Shah N N, Muley A B & Singhal R S 2021 Complexation of curcumin using proteins to enhance aqueous solubility and bio accessibility: Pea protein vis–àvis wheat protein. J. Food Eng. 292: 110258. https://doi.org/10.1016/j.jfoodeng.2020. 110258.

Zhishen J, Mengcheng T & Jianming W 1999 The determination of flavonoid contents in mulberry and their scavenging effects on superoxide radicals. Food chemistry. 64(4): 555–559. https://doi.org/10.1016/S0308–8146(98)00102–2.