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Effect of pretreatment and different drying methods on the antioxidant activities and physico-chemical properties of bitter gourd powder

Most. Shamima Khatun, Nazrul Islam and Shormin Choudhury*

Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka 1207, Bangladesh.
**E-mail: shormin2000@gmail.com*

Abstract

A study was conducted to determine the effect of pretreatment and different drying methods on the antioxidant activities and physicochemical properties of bitter gourd powder. The treatments used were: Un-blanched: (no treatment), hot water blanching (80ºC for 5 min), potassium metabisulphite treated (KMS 0.4% for 5min) with three drying methods *viz.*, sun dry (72 h), oven dry(65ºC 24h), microwave oven dry (500 w for 5 min). The result revealed that the maximum phenol content (16.44, 14.38 and 12.53 mg GAE/100 g) and total carotenoid content (25.55, 22.58 and 21.41 mg/100g) was in KMS-treated microwave oven dried treatment at 1, 2 and 3 months after storage respectively. However, vitamin C (20.48.19.06 and 17.93mg/100 g) and DPPH scavenging activity (90.65, 84.42 and 81.14 %) was found in KMS-treated oven-dried treatment at 1, 2 and 3 months after storage, respectively. It can be concluded that KMS-treated microwave-assisted convective drying of bitter gourd reduced loss of quality attributes while retaining better color and quality characteristics.

Key words: Bitter gourd, pretreatment, drying method, quality attributes, antioxidant activities

Introduction

Bitter gourd (*Momordica charantia* L) is a popular vegetable grown throughout Bangladesh and belongs to the Cucerbitaceae family. It is a rich source of dietary fiber, minerals, low calories, vitamins, and phenolic compounds, which contribute to its antioxidant activity (Krishnendu and Nandani, 2016). Bitter gourd has long been recognized for its antidiabetic, anti-cancer, anti-inflammatory, antiviral, and cholesterol-lowering benefits (Joseph and Jini, 2013). Bitter gourd crop, being highly perishable, is reported to have postharvest losses to the tune of 25-30% during transportation and poor storage facilities (Vatsyayan *et al.,* 2021). Therefore, new technologies must be developed in order to preserve bitter gourds and reduce postharvest losses.

Pretreatment's primary objective is to inactivate enzymes such as polyphenol oxidase, peroxidase, and phenolase, as well as to block some unwanted chemical reactions that produce a product's multiple bad effects on the qulaity. Blanching of vegetable tissue, one of the most commonly used pretreatments, leads to enzyme inactivation, removal of intracellular air, reduced color and flavor loss, and an enhanced drying rate (Deng *et al.,* 2019). Bitter gourd slices treated with potassium metabisulphite (KMS) had the maximum chlorophyll, ascorbic acid, and rehydration ratio, with lower titrable acidity and non-enzymatic browning (Dhotre *et al.,* 2012).

Science and technology have advanced, leading to better drying techniques and higher-quality dried products. The development of new technologies, including vacuuming, microwave cooking, oven drying, and infrared, freeze, and various hybrid drying techniques are being successfully applied to a range of fruits and vegetables (Coklar *et al.,* 2017). Drying is an important procedure for preserving plant materials and lowering the cost of shipping and storing them (Shishir *et al.,* 2018). Powdered items have a longer shelf life and are easier to handle because the real volume and size are decreased to a greater degree (Ankita, 2015).

Drying is a cost-effective alternative to costly postharvest management and selling surplus fruits and vegetables in the market preventing massive waste and make this vegetablesavailable at a fair price during the off-season. The preservation of the bitter gourd would lessen the huge fluctuations in pricing during the picking season and off-season. Processing and conserving bitter gourd as shelf-stable products using efficient drying technologies and effectively utilizing the resultant products would expand its availability throughout the year (Yasmin *et al.,* 2022).

Drying without sufficient pretreatment causes rubbery texture, browning, shrinkage, and loss of sensory and nutritional value. Drying bitter gourd without any pretreatment results in increased browning and a decrease in product quality (Srimagal *et al.*, 2017). To preserve the quality of dried yellow European plum, pretreatments such as blanching (wet and dry), sulphitation, ascorbic acid, sodium chloride (NaCl), and potassium metabisulphite (KMS) have been utilized. (Brar *et al.,* 2020). When dried under the sun, both the product quality and drying rate are low (Sontakke and Salve, 2015).

The pretreatment is aimed to either quality improvement of the final product or improved dry kinetics. There has been little research available of bitter gourd pretreatment under drying methods. To meet the increasing demand of bitter gourd powder, there is an urgent need to assess the pretreatment and drying methods and the suitability of postharvest quality loss assessment during storage period. The purpose of the experiment was to ascertain how different drying methods, such as microwave, oven, and open sun drying, in conjunction with pretreatments such as hot water and KMS, affected the physicochemical characteristics and moisture removal of bitter gourd powder.

Materials and methods

Plant materials and experimental site: Uniform size and shape, fresh-produced bitter gourd cv. BARI hybrid Korola 2 was collected at the green edible stage from the farmers field of Manikgonj, Bangladesh in July 2023. The fruits were then processed in the laboratory after shipment. The experiment was conducted in postharvest laboratory at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, from July to October 2023. The experiment was set up in a completely randomized design design (CRD) with nine treatments and three replications. During the experiment, the average temperature and humidity were 28 ± 2°C and 65±*2%*, respectively.

Treatments: The experiment comprised of two factors: Factor A: three pretreatments *i.e.* T_0: No treatment (control), T_1: Hot water Blanching (80° C for 5 min), T_2: Potassium metabisulphite (KMS 0.4% for 5min) and factor B: three drying methods *viz.*, D_0: Sun dry (72 h), D_1: Oven dry (65°C for 24h), D_2: microwave oven dry (500 w for 5 min).

Storage: The samples were stored at ambient temperature for 3 months and analyzed for microbial and sensory characteristics every 30 days during storage interval.

Vitamin C (mg/100g): 100 mL of a 5% oxalic acid solution was used to create the volume. For the titration, the dye solution 2, 6-dichlorophenol indophenol, was used. The mean observations demonstrated how much dye was required to oxidize a particular quantity of an unknown concentration of L- ascorbic acid solution using L-ascorbic acid as the known sample. The final point of titration which lasted 10 seconds and required a 5 mL solution for the pink color was determined each time. The reading from the burette was recorded.

DPPH radical scavenging activity (%): The DPPH scavenging activity of bitter gourd was determined using Tan *et al.* (2008) method. A stock solution of DPPH was prepared by dissolving 4 mg in 100 mL methanol and stored at -20°C until used. A working standard was prepared by mixing 35 mL of stock solution with 35 mL of methanol and absorbance was observed at 516 nm using a spectrophotometer. 100 µL of Bitter gourd extract was mixed with 1.5 mL of methanolic DPPH and kept overnight in the dark and absorbance was taken at 516 nm. The DPPH scavenging activity was determined using following equation:

DPPH scavenging activity (%) =[(BlankA-Sample A) /BlankA]x 100

Total phenolic compounds (TPC) (mg GAE/100 g)**:** The total phenolic compounds of the samples were determined using Folin-Ciocalteau (FC) assays by Tan *et al.* (2008) with slight modification. Extracted samples of 500 µL were pipetted into test tubes. FC reagent (2 mL) was added into each test tube and was vortexed. Then, the mixtures were left standing at room temperature for 5 mins. An amount of 1.6 mL 7.5% Na_2CO_3 was added into the mixture and vortexed again. The mixtures were allowed to stand for 1 hour in dark at room temperature. The absorbance was measured at 765 nm using a UV-visible spectrophotometer and a calibration curve was prepared using gallic acid at the concentration of 0,0.1, 0.3, 0.5, 0.7, 0.9 and 1.0 mg/ml. Results were expressed as mg gallic acid equivalents (GAE)/100g of dried sample.

Quantification of total carotenoids (TC) (mg/100g): The sample bitter gourd powder (0.01+_ 0.001 g) was taken and weighed in a test tube; seven (7) mL of a 4:3 ethanol-hexane solution was added, protected from light in a cold bath (2 °C) and stirred for 60 min on an orbital shaker (MRC TOS-4030F, USA) at 250 rpm. Subsequently, 1 mL of distilled water was added and stirred for 15 min. The absorbance of the samples at 450nm was read against a hexane blank (97.0% Sigma Adrich, Spain). A Spectrophotometer UV-Vis, Jenway 6320D, was used. The total carotenoid content of the hexane extracts was calculated as follows:

$$TC(mg)/100(g)db = \frac{A_{450} \times 536.85 \times 3}{0.01 \times 137.4}$$

Where 536.85 g/mol is the molecular weight of β-carotene, 3 is the volume (mL) of hexane, 0.01 g is the weight of the added sample, and 137.4 mM^{-1} is the extinction coefficient for β-carotene in hexane.

Total chlorophyll content (mg/100g): For total chlorophyll content measurement, 100 mg of dehydrated bitter gourd fraction was placed in a vial containing 7 mL of dimethyl sulphoxide and chlorophyll was extracted at 65 °C by incubating for 3h. The extract was filtered and made up to 10 mL with dimethyl sulphoxide. The intensity of color was measured at 645 and 663 nm using a spectrophotometer and chlorophyll content was calculated by Arnon's formula, which is given below:

$$\text{Total Chlorophyll} = (0.0202A_{645} + 0.00802A_{663}) \times \text{Dilution factor}$$

Total bacterial count (TBC) and total fungal count (TFC): Total bacterial count in the samples was determined by the dilution plate method using nutrient agar medium and total fungal count in the samples was determined by the dilution plate method using potato dextrose agar medium as reported by as reported by Collins (1976).

Proximate analysis: Proximate composition of the bitter gourd samples was analyzed for their moisture, carbohydrate, crude protein, crude fat, crude ash, and crude fibre contents using standard methods (AOAC, 1995).

Sensory evaluation of dehydrated bitter gourd products: The sensory evaluation of dried bitter gourd products was done by 9-point hedonic scale (Amerine *et al.*, 1967).

Statistical analysis: Statistics 10 (IBM Corp, Armonk, NY, USA) was used for all statistical analyses. The mean value across treatments was refereed statistically significant when $P<0.01$. The graphs were created using Microsoft Excel.

Results

DPPH radical scavenging activity(%): The results revealed that the maximum DPPH scavenging activity was recorded from KMS treated oven dried bitter gourd powder (90.65, 84.42 and 81.14 % at 1, 2 and 3 MAS, respectively) while the minimum was recorded in un-blanched sun dried treatment (34.51, 34.30 and 29.66 % at 1, 2 and 3 MAS, respectively) (Table 1).

Vitamin C content (mg/100g): The pretreatment of KMS dipping and subsequent oven drying retained the maximum vitamin C (20.48, 19.06 and 17.93mg/100 g at 1, 2 and 3 MAS, respectively) and the minimum vitamin C content was recorded in un-blanched sun-dried bitter gourd (18.44, 16.77 and 12.86 mg/100 g at 1, 2 and 3 respectively) (Table 1).

Phenol content (mg GAE/100 g): The results showed that the maximum phenol content was recorded in KMS treated Microwave oven-dried bitter gourd powder (16.44, 14.38 and 12.53 mg GAE/100 g at 1, 2 and 3 MAS, respectively) whereas the minimum was recorded in un-blanched sun-dried bitter gourd (10.94, 8.29, and 6.82 mg GAE/100 g at 1, 2 and 3 MAS, respectively) (Table 1).

Table 1**.** Effect of pretreatment and drying method on DPPH scavenging activity, vitamin C and phenol content of bitter gourd powder at different months after storage (MAS)

Treatment	DPPH scavenging activity (%)			Vitamin C content (mg/100g)			Phenol content (mg GAE/100 g)		
	1 MAS	2 MAS	3 MAS	1 MAS	2 MAS	3 MAS	1 MAS	2 MAS	3 MAS
T_0D_0	34.51h	34.30i	29.66h	18.44g	16.77g	12.86h	10.94f	8.29f	6.82e
T_0D_1	60.40f	59.76g	54.13f	20.09cd	18.50de	15.95f	11.96e	9.18e	7.14e
T_0D_2	50.13g	46.61h	44.07g	19.32f	17.68f	14.93g	12.9d	9.52e	8.51d
T_1D_0	64.06e	63.18f	59.95e	19.77e	18.32e	16.48e	13.15d	9.23e	8.83cd
T_1D_1	74.80d	70.61e	67.99d	20.33ab	18.77bc	17.47b	14.31c	10.83c	10.19b
T_1D_2	80.75c	77.76d	73.79c	20.22bc	18.68b-d	17.23c	15.33b	12.79b	12.10a
T_2D_0	80.07c	79.73c	76.18b	19.88de	18.53c-e	16.94d	12.21e	9.97d	9.28c
T_2D_1	90.65a	84.42a	81.14a	20.48a	19.06a	17.93a	15.6b	10.84c	10.54b
T_2D_2	83.70b	82.61b	80.14a	20.28a-c	18.86ab	17.60b	16.44a	14.38a	12.53a
LSD $_{(0.01)}$	0.49	0.83	1.78	0.24	0.24	0.16	0.56	0.36	0.63
CV (%)	0.30	0.51	1.19	0.51	0.57	0.41	1.73	1.47	2.79

T_0=Un-blanched (no treatment), T1= Hot water blanching (80ºC 5min), T_2= Potassium metabisulphite (KMS0.4%5min), D_0= Sundry (72h), D_1= Oven drying (65ºC for 24h), D_2= Microwave oven drying (500 W for 5 min)

Total chlorophyll and carotenoids (mg/100g): Table 2 shows that the highest total chlorophyll content (28.31, 27.20 and 24.56 mg/100 gm at 1, 2 and 3 MAS, respectively) and carotenoids content on bitter gourd powder (25.55, 22.58 and 21.41 mg/100g at 1, 2 and 3 MAS, respectively) was recorded in KMS treated microwave oven dried bitter gourd powder and the lowest chlorophyll content (10.75, 7.04 and 6.02 mg/100 gm at 1, 2 and 3 MAS, respectively) and carotenoids content (9.06, 7.78 and 6.33 mg/100 gat 1, 2 and 3 MAS, respectively) was recorded from un-blanched sundry.

Overall acceptance: Table.2 illustrated higher sensory acceptability (taste, aroma, and texture) KMS treated microwave oven dry dried bitter gourd powder was found (8.06, 7.90, and 7.43 at 1, 2 and 3 MAS, respectively). On the other hand, the lower result found (7.00, 6.66 and 6.27at 1, 2 and 3 MAS, respectively) was scored by un-blanched sundried samples.

Table 2. Effect of pretreatment and drying method on total chlorophyll, carotenoids and overall acceptability of bitter gourd powder at different months after storage (MAS)

Treatment	Total chlorophyll (mg/100g)			Carotenoids (mg/100g)			Overall acceptability		
	1 MAS	2 MAS	3 MAS	1 MAS	2 MAS	3 MAS	1 MAS	2 MAS	3 MAS
T_0D_0	10.75 h	7.04i	6.02h	9.06g	7.78 f	6.33g	7.00e	6.66f	6.27e
T_0D_1	15.87f	13.60g	10.08g	17.58e	14.61d	12.78 d	7.53cd	7.17de	6.94d
T_0D_2	17.32e	15.05f	13.48 e	18.29d	15.46d	13.05 d	7.67b-d	7.33cd	7.00cd
T_1D_0	13.27g	12.31h	11.40f	9.45g	8.02f	7.31f	7.43d	7.00e	6.46e
T_1D_1	18.88d	16.08 e	13.83de	20.40c	18.48c	17.82c	7.56b-d	7.43b-d	7.13b-d
T_1D_2	21.32c	20.73c	17.23c	21.18b	20.36b	19.03b	7.73bc	7.56bc	7.20a-c
T_2D_0	21.67c	18.25d	14.40d	12.54f	10.47e	10.20e	7.56b-d	7.36cd	7.00cd
T_2D_1	25.14b	23.74b	20.86b	21.41b	19.69b	18.87b	7.83ab	7.67ab	7.33ab
T_2D_2	28.31a	27.20 a	24.56a	25.55a	22.58a	21.41a	8.06 a	7.90a	7.43a
LSD $_{(0.01)}$	0.63	0.79	0.57	0.66	0.94	0.80	0.28	0.29	0.24
CV (%)	1.39	1.96	1.63	1.61	2.60	2.38	1.55	1.70	1.49

T_0=Un-blanched (no treatment), T_1= Hot water blanching (80ºC 5min), T_2= Potassium metabisulphite (KMS 0.4% 5min), D_0= Sundry (72h), D_1= Oven drying (65ºC for 24h), D_2= Microwave oven drying (500 W for 5 min)

Bacterial and fungal count (cfux10^6): Un-blanched sundried bitter gourd powder revealed the highest bacterial counts (11.52, 12.85, and 14.63cfux10^6 at 1, 2, and 3 months after storage (MAS), respectively) and fungal counts (0.53, 3.50, and 4.10cfux10^6 at 1, 2, and 3 MAS, respectively). Whereas bacterial counts at 2 and 3 MAS were 6.75 and 7.10 cfux10^6, respectively, in KMS-treated microwave oven-dried samples, the lowest bacterial count (4.78 cfux10^6 at 1 MAS) was found in KMS-treated oven-dried samples. Additionally noted in the KMS-treated microwave oven-dried treatment was the lowest fungal count (1.30 and 1.57cfux10^6 at 2 and 3 MAS, respectively) (Table 3).

Proximate composition: Proximate composition of bitter gourd content is significantly different in pretreatment and drying methods (Table 4). Results revealed that the maximum ash (13.17, 12.78 and 12.53 % at 1, 2 and 3 MAS, respectively), fiber (3.41, 3.24 and 3.16% at 1, 2 and 3 MAS, respectively) content was recorded from KMS treated microwave oven dried powder and lipid (4.60, 4.38 and 3.95 % at 1, 2 and 3 MAS, respectively) KMS treated oven dried powder whereas the minimum ash (10.17, 9.83 and 9.66% at 1, 2 and 3 MAS, respectively), fiber (2.16, 2.11 and 2.01 % at 1, 2 and 3 MAS, respectively) and lipid (2.80, 2.42 and 2.16 % at 1, 2 and 3 MAS, respectively) was recorded from un-blanched sundry bitter gourd powder.

Table 5 illustrated the maximum protein (8.05, 7.35 and 6.84 % at 1, 2 and 3 MAS, respectively) in KMS-treated oven dried powder. The lowest protein (6.03, 5.50 and 5.03 % at 1, 2 and 3 MAS, respectively), the highest moisture (10.21, 10.92 and 11.86% at 1, 2 and 3 MAS, respectively) and carbohydrate (68.61, 69.20 and 69.28 % at 1, 2 and 3 MAS, respectively) content was recorded in un-blanched sun dried powder. However, the minimum moisture (7.38, 7.59 and 7.90% at 1, 2 and 3 MAS, respectively) and carbohydrate (63.56, 64.78 and 65.87 %) at 1, 2 and 3 MAS, respectively) content was recorded by KMS-treated microwave oven dried powder.

Table 3. Effect of pretreatment and drying method on bacterial and fungal count (cfu/gm) of bitter gourd powder at different months after storage (MAS)

Treatment	Bacterial count (cfux10^6)			Fungal count (cfux10^6)		
	1 MAS	2 MAS	3 MAS	1 MAS	2 MAS	3 MAS
T_0D_0	11.52a	12.85a	14.63a	0.53a	3.50 a	4.10a
T_0D_1	7.46c	9.54c	11.47b	0.00c	2.23 c	3.00 c
T_0D_2	8.13b	8.33e	10.65c	0.00c	1.68f	2.17g
T_1D_0	7.13d	9.92b	10.43c	0.00b	2.96b	3.41b
T_1D_1	7.03de	8.08e	9.36 de	0.00c	2.07d	2.60e
T_1D_2	6.83ef	6.90fg	7.76 f	0.00c	1.50g	1.83h
T_2D_0	6.75f	8.68d	9.73d	0.00c	2.16cd	2.82d
T_2D_1	4.78g	7.17f	9.04 e	0.00c	1.90e	2.32f
T_2D_2	6.68f	6.75g	7.10g	0.00c	1.30h	1.57i
LSD $_{(0.01)}$	0.26	0.29	0.56	0.02	0.12	0.14
CV (%)	1.53	1.40	2.34	4.37	2.40	2.14

Table 4. Effect of pretreatment and drying method on ash, fiber and lipid content (%) of bitter gourd powder at different months after storage (MAS)

Treatment	Ash content (%)			Fiber content (%)			Lipid content (%)		
	1 MAS	2 MAS	3 MAS	1 MAS	2 MAS	3 MAS	1 MAS	2 MAS	3 MAS
T_0D_0	10.17 h	9.83f	9.66g	2.16g	2.11f	2.01g	2.80g	2.42f	2.16d
T_0D_1	10.67g	10.27ef	9.93fg	2.29f	2.24e	2.15ef	3.80d	3.34d	2.98bc
T_0D_2	11.50 de	11.03c	10.50de	2.58 d	2.40d	2.28d	3.80d	3.17e	2.92bc
T_1D_0	11.00fg	10.57de	10.27ef	2.20g	2.15f	2.09fg	3.23f	3.04e	2.79c
T_1D_1	11.17 ef	10.97cd	10.67de	2.47e	2.39d	2.24 de	4.15b	3.85b	3.15bc
T_1D_2	11.83 cd	11.37c	10.83cd	2.90c	2.82c	2.47c	3.95c	3.64c	3.29b
T_2D_0	12.00 bc	11.30c	11.23c	2.85c	2.80 c	2.72b	3.60e	3.43d	3.12bc
T_2D_1	12.33b	12.00b	11.73b	3.03b	2.92b	2.76b	4.60a	4.38a	3.95a
T_2D_2	13.17a	12.78a	12.53a	3.41a	3.24a	3.16a	4.48a	4.33a	3.88a
LSD $_{(0.01)}$	0.45	0.45	0.42	0.07	0.08	0.10	0.12	0.14	0.38
CV (%)	1.66	1.70	1.64	1.13	1.34	1.68	1.40	1.73	5.11

Table 5. Effect of pretreatment and drying method on protein, moisture and carbohydrate content (%) of bitter gourd powder at different months after storage (MAS)

Treatment	Protein content %			Moisture content %			Carbohydrate content %		
	1 MAS	2 MAS	3 MAS	1 MAS	2 MAS	3 MAS	1 MAS	2 MAS	3 MAS
T_0D_0	6.03f	5.50e	5.03e	10.21a	10.92a	11.86a	68.61a	69.20a	69.28a
T_0D_1	7.43cd	6.28cd	5.44cd	10.05b	10.33b	11.70b	65.75c	67.53bc	67.78d
T_0D_2	7.20e	6.17d	5.37d	9.57c	10.05c	10.19 d	65.34de	67.16cd	68.72bc
T_1D_0	7.23de	6.27cd	5.30d	10.07b	10.15c	10.41c	66.26b	67.81b	69.13ab
T_1D_1	7.72b	6.50 b	5.64bc	9.03d	9.29 d	9.88e	65.46cd	66.98d	68.41c
T_1D_2	7.70 b	6.42bc	5.64bc	8.58f	8.89e	9.08f	65.02e	66.85d	68.67bc
T_2D_0	7.45c	6.41bc	5.67b	8.89e	9.01e	9.75e	65.21de	67.03d	67.48d
T_2D_1	8.05 a	7.35a	6.84a	8.25g	8.39f	8.60g	63.73f	64.94e	66.10e
T_2D_2	7.98a	7.25 a	6.65a	7.38h	7.59g	7.90h	63.56f	64.78e	65.87e
LSD $_{(0.01)}$	0.21	0.17	0.20	0.13	0.15	0.13	0.42	0.42	0.54
CV (%)	1.22	1.16	1.47	0.58	0.71	0.55	0.27	0.26	0.34

T_0=Un-blanched (no treatment), T_1= Hot water blanching (80°C 5min), T_2= Potassium metabisulphite (KMS 0.4% 5min), D_0= Sundrying (72h), D_1= Oven drying (65°C for 24h), D_2= Microwave oven dry (500 W for 5 min)

Discussion

Pretreatment before drying could influence DPPH concentrations, possibly due to structural changes in the food that facilitate the dehydration process as well as the inactivation of enzymatic reactions in bitter gourd (Aabhishek *et al.,* 2021). Bunkar *et al.* (2020) also observed that oven drying (70°C) certainly increased antioxidant activity due to an increase in the concentration of bioactive chemicals in the food matrix without causing significant loss. Higher drying temperatures may cause an increase in antioxidant activity because they break down cell walls, releasing antioxidants, particularly vitamin C (Irondi *et al.*, 2017). The reduction of ascorbic acid was higher in sun drying than in oven drying treatment (Singh and Sagar, 2013). In our findings, the bitter gourd samples treated with KMS contained more vitamin C, which also might stand against oxidative damage and consequently comparatively hold higher carotenoids than other treatments. Ascorbic acid levels were higher in dehydrated spine gourd slices treated with KMS compared to controls (Sagar and Singh, 2022). This might be due to KMS preserving ascorbic acid during the dehydration process by inhibiting oxidative changes in ascorbic acid. Hence, ascorbic acid retention was better in KMS-treated samples. A decrease in the concentration of natural ascorbic acid during raw material processing may have contributed to the reduction in total carotenoids with the advancement of storage periods (Srilatha *et al.,* 2021). Yilmaz *et al.* (2021) revealed that, regarding the drying time, color characteristics, chlorophyll content, and nutrients, the microwave drying method operating at 600 W proved to be the most effective. Vedasree *et al.* (2023) found that without proper pretreatment, bitter gourd loses some of its chlorophyll content during drying. The total chlorophyll concentration was higher in the KMS (0.2%) solution for 20 minutes with microwave oven dried spine gourd, indicating that the antioxidant protection provided by the KMS may have reduced the browning of the dried spine gourd (Sagar and Singh, 2022).

In our results, the overall acceptance score of the sun drying system was poor in sensory traits due to its slower drying rate and fluctuating temperature, which led the sensory traits to its poor conditions. The dehydrated bitter gourd powder was excellent in color, flavor, and texture and it tasted good under microwave oven drying followed by oven drying. Osmo pretreated (KMS and NaCl) samples maintained the color, appearance, texture and taste of the storage product, resulting a higher overall acceptance score compared to control treatment (Kusat *et al.*, 2021). The moisture content of bitter gourd gradually increased with the increase in storage period. Tolera and Abera (2017) explained that the lower moisture content in the treated sample might be attributed to the osmotic pressure in the osmotic solution, forcing the moisture of the internal tissues to come out even before drying. Bahiram *et al.* (2020) reported that the increase in moisture was observed in all the samples but it was more in the sun-dried sample than other samples. Zahoor and Khan (2019) also found that in case of microwave, there was a rapid water removal because of an internal pressure generated in the sample that lead to the higher rate of energy transfer to the sample, leading to higher steam pressure and increased the drying rate.

In our present findings, the minimum microbial count (fungus and bacteria) was observed in microwave oven drying followed by oven-drying. This might be due to lowering the moisture content on the Microwave oven-dried sample, this lower moisture leads to less microbial growth. Pham *et al.* (2017) stated that bitter gourd drying could extend the shelf life of processed product and prevent microbiological growth by lowering moisture content. Chemical treatments can minimize microbial growth and reduce the degradation of texture in the minimally processed product. Dipping of bitter gourd in KMS effectively retard the microbial population by arresting microbial protein synthesis. Srilatha *et al.* (2021) reported that calcium salts may arrest water activity, which can lead to slow microbial growth. Temperature increases the amount of bound phenolic compounds that may be extracted, which increases garlic's phytochemical content and antioxidant activity (Alide *et al.,* 2020). Snoussi *et al.* (2021) revealed that total phenolic content degradation occurred more at lower temperatures than at higher temperatures drying, resulting in a faster release of phytochemicals and secondary metabolites, which trigger the maximum phenol production.

Our findings are consistent with those reported by Kumar *et al.* (2016), who found a gradual decrease in total ash content as the storage period of bitter gourd progressed. Vernekar *et al.* (2019) reported that KMS-treated dehydrated betel leaf had a greater total ash content than the control treatment. Microwave-dried apple powder contains more polysaccharides and fibers, as eliminating moisture at a higher temperature could result in the cell wall breaking down of the polysaccharide network (Rana *et al.*, 2015). The lipid content of bitter gourd decreased with increasing storage time. Mozumder *et al.* (2012) observed that the lipid contents of tomato powder treated with $CaCl_2$+KMS had higher lipid than the others because of its lowest moisture content. Biswas *et al.* (2018) reported that protein content decreased as storage time increased for control conditions compared to that of oven-dry treatment. Changes in protein content could be attributed to a process, such as non-enzymatic browning, which was found to be greater in control samples and less in $CaCl_2$ + KMS treatment. Our results are in agreement with data presented by Marquez-Cardozo *et al.* (2021), who found that the different drying methods significantly affected the carbohydrate content of powdered samples as it was related to the moisture content, protein, fiber, fat and ash values.

The physicochemical properties and antioxidant capacities of bitter gourd powder was affected by the different pretreatment and drying methods. From this study, it can be concluded that the pretreatment of KMS (0.4%) in the microwave oven at 500w for 5 min resulted in the best quality product and oven drying at 65 ºC for 24h was next to earlier treatment. Pretreatment with drying allows it to be stored for a longer period. In general, KMS-treated microwave oven drying showed higher phenol, total carotenoid, ash, and fiber content, while the KMS-treated oven drying treatment exhibited higher vitamin C and DPPH levels. Both methods demonstrated improved textural qualities and antioxidant activity, though they resulted in increased time consumption.

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