Effect of preparation techniques and pre-treatments on quality of carrot powder

ABSTRACT

The experiment was carried out to study effects of preparation techniques and pre-treatment on quality of carrot powder. In this experiment; total of 18 treatments were used for dehydration of carrot into powder using combinations of different treatments *viz*. preparation techniques as Factor-1 ["Shredding" (T_1), "Crushing" (T_2) and "Slicing" (T_3)]; microwave pre-treatments as Factor-2 [Control (M_1), Microwave pre-treatment 450 W for 30 seconds (M_2) and microwave pre-treatment 450 W for 60 seconds (M_3)] and pressing as Factor-3 [without pressing (P_1) and pressing (P_2)]. The results of the investigation revealed that best quality carrot powder can be obtained from carrot which was prepared by dehydrating crushed materials by giving microwave for 60 seconds followed by pressing ($T_2M_3P_2$) and carrot powder obtained from this treatment possess higher rehydration ratio, dehydration ratio and sensory score while lowest drying time, moisture content, water activity, reducing sugars and non-enzymatic browning (NEB). While, the carrot powder which was prepared by dehydrating crushed materials by giving microwave pre-treatment for 60 seconds followed by pressing ($T_2M_3P_2$) exhibited minimum changes in nutritional as well as sensory attributes during six months' storage when packed in polypropylene bags of 400-gauge thickness. The carrot powder can be prepared by dehydrating crushed materials by giving microwave pre-treatment for 60 seconds followed by pressing ($T_2M_3P_2$) and the powder can remain microbiologically safe for storage period of six months.

Keywords: Carrot, Powder, dehydration, Quality, Pre-treatments

INTRODUCTION

Among major vegetables, carrot (*Daucus carota* L.) belonging to Apiaceae family is the most important root crop grown throughout the world. It is a root vegetable, usually orange, purple, red, white or yellow in color, with a crisp texture when fresh. It is a rich source of β-carotene and contains other vitamins, like thiamine, riboflavin, vitamin B-complex and minerals (Jabbar *et al.*, 2013). The carrot is consumed in different forms as raw, juice, salads, cooked vegetable and sweet dishes etc. Carrots provide great health benefits to the human body as they are good source of carotenoids, bioactive compounds, vitamins and minerals (Qin *et al.*, 2005). Bioactive compounds present in the carrots are α- and β-carotene, phenolic acids and lycopene which are responsible for its antioxidant activity. Carrot contains approximately 86.00 per cent moisture, 10.60 g carbohydrates, 0.20 g fat, 1.20 g fiber, 1890 µg carotene, 0.04 g thiamine, 0.02 g riboflavin, 0.60 g niacin, 530.00 mg phosphorus, 1.10 g minerals, 3.00 mg vit C and 26.60 µg total phenolic content per 100 g (Gopalan *et al*., 2004). Due to its good flavor and nutrition, carrot is regarded as very important vegetable owing to its various properties like anticancer, anti-anemic, antioxidant, sedative and healing which are directly related to human health (Shivhare*et al.*, 2009). Due to perishable and seasonal nature of carrot, it is not possible to make fresh carrot available throughout the year. Therefore, consumer demand has increased toward processed foods which have more natural flavour and colour with high nutritional quality and sufficient storage safe for distribution and consumption. This can be achieved by adopting suitable processing methods which inactivate micro-organisms as well as enzymes with little loss of pigments, flavour compounds and vitamins (Dede *et al.*, 2007).

Dehydrated carrot in the form of grating can be used in the preparation of *halwa*, discs made in to chips (Khan, 2012). Pre-treatment improves nutritional, sensorial and functional properties of the dehydrated food without changing its integrity. It also improves the texture as well as stability of the pigment during dehydration and the storage of dehydrated product (Kumar and Kumar, 2011). Carrots are dehydrated in the form of slices, shreds, crushed, cubes and strips. High solids and freedom from woody fiber are desired qualities of carrots to be dehydrated. The low rehydration ratio, discolouration and development of off-flavour are the commonly reported problems with dehydrated carrot products. Removal of biologically active water is the main task while preserving food (Sra *et al.*, 2014) by reducing the moisture contents to a level, which allows safe storage over an extended period of time with microbial safety. Very limited literature is available on effect of preparation techniques, microwave pre-treatments and preservatives on quality of carrot powder during storage. Thus, the present investigation was carried out to study the effect of preparation techniques, microwave pre-treatments and preservatives on quality of carrot powder.

MATERIALS AND METHODS

Raw materials: Fresh matured but tender, disease and injury free, orange colored carrots (*var.*Chantney) selected and purchased from Morarji yard, APMC, Navsari. The carrots were cleaned and used for further processing into dehydrated powder.

Experiment detail:A total of 18 treatments were used for dehydration of carrot into powder using combinations of different treatments *viz.* preparation techniques as Factor-1 ["Shredding" (T_1), "Crushing" (T_2) and "Slicing" (T_3)]; microwave pre-treatments as Factor-2 [Control (M_1), Microwave pre-treatment 450 w for 30 seconds (M_2) and microwave pre-treatment 450 w for 60 seconds (M_3)] and pressing as Factor-3 [without pressing- Control (P_1) and pressing for juice extraction (P_2)].

Methodology: The defective as well as undesirable carrots were removed while sorting. Then carrots were thoroughly washed to remove any adhering dust and dirt particles. After washing, the carrots were cut from end and top to remove undesirable portions with stainless steel (SS) knife. Then cut carrots were shredded, crushed and slices (2-3mm) with the help of shredder, crusher and slicer machines (Factor 1).The prepared shreds, crushed materials and slices of carrots (Factor-1) were subjected to microwave pre-treatments (Factor-2). After microwave pre-treatments, the shreds, crushed materials and slices were subjected to pressing (Factor-3) for single strength juice extraction followed by loading into mechanical dehydrator using three stage dehydration temperatures (75 ^{o}C for 2 hours, 65 ^{o}C for 2 hours and 60 ^{o}C for about 11-12 hours) till final moisture content of 5.50 ± 1% as reported by Raj *et al.* (2004) for dehydration of onions. After dehydration, dried shreds, crushed materials and slices were ground into powder using grinder. The prepared powder was packed in polypropylene bags of 400-gauge thickness and stored at ambient temperature to evaluate the nutritional as well as sensory quality of developed products during six months' storage. Principal steps used for dehydration of carrots into powder are illustrated in Fig.1.

Selection of carrots

↓
Washing
↓
Preparation techniques
↓
Pre-treatment
(As per treatments details)
↓
Dehydration (Three stage dehydration temperatures of 75^{o}C for 2 hours, 65^{o}C for 2 hours and 60^{o}C till drying approx. 11-12 hours)
↓
Powder preparation and packaging (Polypropylene bag 400 gauge)
↓
Storage (ambient storage) and analysis

Fig 1: Principal steps used for dehydration of carrot into powder

Physico-chemical parameters of fresh carrots used for dehydration (n=10) were recorded. The powder recovery was arrived by recording the final weight of powder obtained after drying and total weight of raw materials and expressed as recovery per cent. The moisture was estimated by drying the weighted samples in hot air oven at 70±2°C to a constant weight (AOAC 1984). The beta-carotene content of the samples was determined by the method as detailed by Ranganna (1997). The powder was evaluated for sensory qualities on the basis of overall acceptability by a panel of 7-10 judges on a 9-point Hedonic scale (Amerine *et al.* 1965). The data pertaining to physico-chemical characteristics of powder were analysed statistically by following completely randomized design (Panse and Shukhatme (1967). Each treatment was replicated thrice.

RESULTS AND DISCUSSION

Physico-Chemical Attributes of Fresh Carrots: The physico-chemical characteristics of fresh carrots which were used for the preparation of juice and powder are given in Table 1. The data on physical parameters of fresh carrots revealed the mean weight, peeling and trimming losses of the carrots in the range of 75.45 g and 7.40 per cent having orange colour of skin/ peel and flesh. The data on chemical parameters of carrots revealed mean moisture, TSS, acidity, reducing sugars, non-reducing sugars, total sugars, beta-carotene, proteins, crude fibre, ascorbic acid in the range of 9.53 ^{o}Brix, 0.12 %, 2.74 %, 4.15 %, 6.89 %, 38.65 mg/100g, 0.95 %, 1.80 % and 3.91mg/100g, respectively. Our result in present investigation for physico-chemical parameters of carrots are similar to earlier studies as reported by Gopalan *et al*. (2004).The chemical constituents of carrot reported to contains 86 % moisture with 9.55 °Brix TSS, 2.77 % reducing sugars, 6.92 % total sugars, 0.12 % acidity, 10.6 g carbohydrates, 0.2 g fat, 1.2 g fiber, 3965 micro g beta-carotene and 3 mg per 100 g vitamin C (Gopalan *et al.*, 2004). Sharma *et al.* (2012) also reported similar variations for moisture (86 to 88 %), carbohydrate (6 to 10.6 %), crude fiber (1.2 to 2.4 %), total sugars (5.6 %), beta-carotenes (39.6 mg/ 100 g).

Table 1: Physico-chemical characteristics of fresh carrot used for dehydration

Parameters*	**Mean**
Weight of carrot (g)	75.45
Peeling and trimming loss (%)	7.40
Skin / peel colour, visual	Orange
Flesh colour, visual	Orange
Moisture (%)	86.12

TSS(^{o}Brix)	9.53
Acidity (%)	0.12
Total Sugars (%)	6.89
Reducing sugars (%)	2.74
Non-reducing sugars (%)	4.15
Beta-carotene (mg/100g)	38.65
Proteins (%)	0.95
Crude fibre (%)	1.80

QUALITY OF POWDER: As per dehydration experiment treatment details, one factor was taken to study the effect of pressing along with control (without pressing) on the quality of the dehydrated carrot powder. The aim of the factor was to evaluate the feasibility of pressing for juice extraction, to utilize left over carrot pomace for dehydration and to evaluate dehydrated carrot powder on the basis of physico-chemical, sensory and microbial characteristics. Thus, the prepared dehydrated carrot powder was evaluated for physico-chemical, sensory and microbial characteristics to study the effect of different treatments during six-month storage. In addition, juice yield / recovery (single strength juice) obtained due to pressing pre-treatment used prior to dehydration was also documented. However, for juice extraction prior to dehydration only two factors viz. preparation techniques (T) and microwave pre-treatments (M) were taken into consideration while pressing level (P_2) was common. Among different preparation techniques, it was possible to extract the juice only from shredded and crushed carrots by pressing treatment. It was not possible to extract carrot juice by pressing treatment from the slices. Hence two levels of preparation techniques (T_1 and T_2) were considered for juice extraction by pressing.

Powder yield

The perusal of data pertaining to effect of different treatments on powder yield content of carrot powder during six months storage period have been presented in Table 2.

*Effect of preparation techniques:*Among different preparation techniques (T), the powder yield of carrot powder varied significantly between 9.09 and 12.38 %, with minimum powder yield (9.09 %) in carrot powder which was prepared by giving crushing treatment (T_2) and maximum powder yield (12.38 %) in slicing (T_3). The minimum powder yield of carrot which was prepared by giving crushing treatment might be attributed to higher juice recovery in carrot juice. Crushing of carrots resulted immediate release of the moisture and its soluble compounds upon pressing due to more disintegration of the cell structure. Wilczynski *et al.* (2019) also reported higher yield (71.6 %) of apple juice of different varieties in screw type of juice extractor due to crushing action of fruit tissues as compared to basket press (61.9 %). Raj *et al*(2011) reported yield of potato flour among different potato cultivars varied from 13.23 to 20.73 per cent, with maximum yield in Kufri Chipsona-2 followed by Kufri Chipsona-1 (20.63 %) and Kufri Chandramukhi (18.53 %) and minimum in Kufri Jyoti followed by Kufri Badshah (14.70%). The increase in dehydration ratio of the flour in blanching treatment might be attributed to leaching losses of the nutrients and solids.

*Effect of microwave pre-treatment:*Data shows that among different microwave pre-treatments grand mean powder yield (M) of microwave pre-treated carrot powder varied significantly between 10.16 and 10.96 %, with minimum powder yield (10.16 %) in carrot powder pre-treated with microwave for 60 seconds (M_3) and maximum powder yield (10.96 %) in carrot powder prepared without microwave pre-treatment (M_1). The differences of powder yield in carrot under different microwave pre-treatments might be due to the extraction efficacy of soluble compounds owing to variation in pre-treatment time. The exposure to microwave causes disintegration of the cell structure due to vibration of the water molecules and resulted higher juice recovery upon pressing and lower powder yield because the juice itself contains soluble solids long with other micro-nutrients. Gerard and Roberts (2004) reported that Fuji and McIntosh apple mashes heated to bulk temperatures of 60 ^{o}C by 2450 MHz microwave oven at 1500 W increased juice yield when mash was treated before pressing. Rayman and Baysal (2011) also reported increase carrot juice yield of 9.7 % (50.90 to 55.84 %) juice yield due to applications of the electrical methods (electroplasmolysis + microwave). The juice yield was found to vary with the variation of voltage and time of EP application. These treatments affect the cell permeability and make the juice extraction process easier.Leeratanarak*et al.* (2006) reported that blanching help to increase the dehydration ratio of the product which represents the decrease in the yield of the dehydrated product. The decrease in yield of the flour in blanching treatment might be attributed to leaching losses of the nutrients and solids

*Effect of pressing:*Further, it was observed that mean powder yield (P) of the carrot when dehydrated followed by pressing treatment varied significantly from 9.19 to 11.87 %, with minimum powder yield (9.19 %) in carrot powder when dehydrated followed by pressing treatment (P_2) and maximum powder yield (11.87%)in carrot powder when dehydrated without pressing treatment (P_1). The minimum powder yield of carrot which was prepared for dehydration by giving pressing treatment might be attributed to transfer of soluble solids to carrot juice during extraction process and thus decreasing the weight of soluble solids for dehydration. Wilczynski *et al*. (2019) also reported higher yield (71.6 %) of apple juice of different varieties due to higher pressure in screw type juice extractor as compared to basket press (61.9 %) leaving less pomace for dehydration.Leeratanarak*et al.* (2006) reported that blanching help to increase the dehydration ratio of the product which represents the decrease in the yield of the dehydrated product. The decrease in yield of the flour in blanching treatment might be attributed to leaching losses of the nutrients and solids.

*Effect of treatment interactions:*Interaction of microwave and pressing treatments (MP) depicted variation in carrot powder yield from 8.64 to 12.16 %, with minimum powder yield of 8.64 % in powder which was dehydrated by pressing the raw material followed by pre-treatment with microwave for 60 seconds (M_3P_2) and maximum powder yield (12.16 %) in powder which was dehydrated without pressing and microwave pre-treatment (M_1P_1). Interaction of preparation techniques and pressing technique (TP) depicted variation in carrot powder yield from 6.72 to 12.53 %, with minimum powder yield 6.72 % in powder which was prepared by crushing technique (T_2P_2) and maximum powder yield 12.53 % in powder which was dehydrated by without pressing and microwave pre-treatment (T_3P_1). Interaction of preparation techniques, microwave and pressing techniques (TMP) depicted variation in carrot powder yield from 6.20 to 12.92 %, with minimum powder yield of 6.72 % in powder which was prepared by dehydrating crushed materials by giving microwave for 60 seconds followed by pressing treatment ($T_2M_3P_2$) and maximum powder yield of 12.92 % in powder which was prepared by dehydrating carrot slices without microwave and pressing pre-treatment ($T_3M_1P_1$). Interactions of TxM,TxP, MxP, TxMxP were found to have significant effect.

Dehydration rate

The perusal of data pertaining to effect of different treatments on dehydration rate (g/min) of carrot powder during dehydration has been presented in Table 3.

*Effect of preparation techniques:*Among different preparation techniques (T), the dehydration rate of carrot powder varied significantly between 6.89 and 8.28 (g/min), with minimum dehydration rate (6.89 g/min) in carrot powder which was prepared by giving crushing treatment (T_2) and maximum dehydration rate (8.28 g/min) in slicing (T_3). The minimum dehydration rate of carrot which was prepared by giving crushing treatment might be attributed to less moisture available in carrot pomace for drying after pressing because pressing treatment causes yield of juice is higher upon and pomace remained with less moisture. Crushing of carrots followed by pressing resulted immediate release of the moisture due to more disintegration of the cell structure and thus less available moisture remained in carrot pomace for drying. Leeratanarak*et al.* (2006) reported that blanching time had effect on the drying rates at all drying temperature in hot air drying. The samples prepared by blanching dried faster than the unblanched samples. The increase in drying rate of the flour in blanching treatment might be attributed to faster diffusion of the water out of the tissues. Hatamipour*et al.* (2007) reported that increase of blanching time decreased drying rate. Dinrifo (2012) recorded variations in drying rate of sweet potato slices when pre-treated with blanching at 100^oC and sulphitation with sodium metabisulphite. The pre-treatment reduces the resistance to moisture transport thereby increasing the drying rates. The drying of sweet potato slices exhibited higher drying rates for pre-treated samples than for untreated samples, especially at higher temperatures.

*Effect of microwave pre-treatment:*Data shows that among different microwave pre-treatments grand mean dehydration rate (M) of microwave pre-treated carrot powder varied significantly between 7.56 and 7.83 (g/min), with maximum dehydration rate (7.83 g/min) in carrot powder prepared pre-treated with microwave for 60 seconds (M_3) and minimum dehydration rate (7.56 g/min) in carrot powder pre-treated with microwave for 30 seconds (M_2). The differences of drying rate during carrot dehydration under different microwave pre-treatments might be due to the extraction efficacy of soluble compounds owing to variation in pre-treatment time. The exposure to microwave causes disintegration of the cell structure due to vibration of the water molecules and resulted easy water removal during dehydration. Sabry *et al.*(2016) reported that microwave treatment of carrots slices (2-3 MM) with 360 watt for 6 min can reduce weight loss from 81.75 % moisture content to 52.32 % on dry weight basis with slight reduction of drying period as compared to other treatments. Kaur and Singh (2014) reported that drying of beet slices at high air temperature (75°C) followed by high microwave power (1080 W) witnessed increased drying rates and substantial shortening of the drying time. Andres *et al.* (2004) reported that when drying of apple with combined air microwave system, the drying rate curve could be divided in four periods limited by four critical points and results faster drying.

*Effect of pressing:*Further, it was observed that mean Dehydration rate (P) of the carrot powder when dehydrated followed by pressing treatment varied significantly from 6.82 to 8.50 (g/min), with minimum dehydration rate (6.82 g/min) in carrot powder when dehydrated followed by pressing treatment (P_2) and maximum dehydration rate (8.50 g/min) in carrot powder when dehydrated without pressing treatment (P_1). The minimum dehydration rate of carrot which was prepared by giving pressing treatment might be attributed to less moisture available in carrot pomace for drying after pressing because pressing treatment causes higher juice extraction and pomace remained with less moisture. Pressing of prepared carrots resulted immediate release of the moisture due to more disintegration of the cell structure.

*Effect of treatment interactions:*Interaction of preparation techniques, microwave and pressing techniques (TMP) depicted variation in carrot powder dehydration rate from 5.00 to 9.08 g/min , with minimum dehydration rate of 5.00 g/min in powder which was prepared by dehydrating crushed materials by giving microwave for 30 seconds followed by pressing treatment ($T_2M_2P_2$) and maximum dehydration rate of 9.08 g/min in powder which was prepared by dehydrating shredded materials by giving microwave for 60 seconds without pressing pre-treatment($T_1M_3P_1$).Interactions of TxM,TxP, MxP, TxMxP were found to have significant effect. However, interactions of MxP were found to have non-significant effect. Abano *et al.* (2011) reported improvement in drying rates of the garlic slices followed by drying temperature at 45 ^oC compare to control dried samples that were harder than all the pre-treated dried samples. Wu *et al.* (2013) reported higher drying rates and greater effective diffusivities under catalytic infrared (CIR) than hot air (HA) heating before the moisture contents reached the range of 16 to 30% on a wet basis (w.b.).

Rehydration ratio

The perusal of data pertaining to effect of different treatments on rehydration ratio of carrot powder during has been presented in Table 4.

*Effect of preparation techniques:*Among different preparation techniques (T), the rehydration ratio of carrot powder varied significantly between 4.73 and 6.55, with maximum rehydration ratio 6.55 in carrot powder which was prepared by giving crushing treatment (T_2) and minimum rehydration ratio 4.73 in slicing (T_3). Loesecke and Willard (1955) reported that the rehydration characteristics of the dehydrated food are influenced by processing conditions as well as sample composition used in dehydration.

*Effect of microwave pre-treatment:*Data shows that among different microwave pre-treatments grand mean rehydration ratio (M) of microwave pre-treated carrot powder varied significantly between 5.54 and 6.08, with maximum rehydration ratio (6.08) in carrot powder pre-treated with microwave for 60 seconds (M_3) and minimum rehydration ratio (5.54) in carrot powder prepared without microwave pre-treatment for (M_1). Pandit (2015) reported similar variations in rehydration ratio (2.20 to 2.94) of dehydrated elephant foot yam due to variation of microwave exposure time and power. This can be explained by the high internal pressure produced by microwave hating which can cause structure of carrot slices to expand and puff during dehydration and thus causing high rehydration ratio. Similar results were obtained by several researchers in other foods viz. kiwi fruits (Maskan, 2001) and onions (Kalse*et al.,* 2012). Kaur and Singh (2014) reported that rehydration characteristics of beetroot improved for samples dehydrated at 55°C air temperature followed by high microwave power (1080 W) which can be helped in reduction of shrinkage. Zielinska *et al.* (2018) also reported increase in rehydration ratio due to microwave treatment in dried cranberries.

*Effect of pressing:*Further, it was observed that mean rehydration ratio (P) of the carrot powder when dehydrated followed by pressing treatment varied significantly from 5.49 to 6.06, with maximum rehydration ratio (6.06) in carrot powder when dehydrated by pressing treatment (P_2) and minimum rehydration ratio (5.49) in carrot powder when dehydrated without pressing treatment (P_1). Loesecke and Willard (1955) reported that the rehydration characteristics of the dehydrated food are influenced by processing conditions as well as sample composition used in dehydration.

*Effect of treatment interactions:*Interaction of preparation techniques and pressing technique (TP) depicted variation in carrot powder rehydration ratio from 4.59 to 6.72, with maximum rehydration ratio of 6.72 in powder which was prepared by crushing technique followed by pressing treatment (T_2P_2) and minimum rehydration ratio of 4.59 in powder which was dehydrated by slicing technique without pressing treatment (T_3P_1).

Moisture

The perusal of data pertaining to effect of different treatments on moisture content of carrot powder during six months storage period have been presented in Table 5.

*Effect of preparation techniques:*Among different preparation techniques (T), the moisture of carrot powder varied significantly between 5.91 and 7.53 %, with minimum moisture in carrot powder which was prepared by giving crushing treatment (5.97 %) and maximum moisture in slicing (7.53%). The lower moisture in carrot powder prepared using crushing treatment followed by pressing might be attributed to release of most of water from the tissue due to pressing and higher dehydration rate for left over carrot pomace which requires less dehydration time for drying. Earlier studies also observed similar results for moisture in treatments which requires less dehydration time for okra, cauliflower and onions (Anon., 2017). Lower moisture and water activity was also observed in food products which requires less dehydration time as reported by Vaghashiyaet al (2016) in dehydrated Aloe vera gel and Zinzala (2019) for bael candy. Alam *et al.* (2013) variations in water activity in dried carrot pomace powder prepared using different pre-treatments i.e., water blanching (WB), steam blanching (SB), citric acid blanching (CB), potassium metabi sulphate (KMS) dipping after blanching (WBS) and reported highest water activity (0.558) in untreated samples and lowest (0.379) value in WBS pre-treated samples.

*Effect of microwave pre-treatment:*Data shows that among different microwave pre-treatments grand mean moisture (M) of microwave pre-treated carrot powder varied significantly between 6.32 and 7.13 %, with minimum moisture (6.32 %) in carrot powder pre-treated with microwave for 60 seconds (M_3) and maximum moisture (7.13 %) in carrot powder prepared without microwave pre-treatment (M_1). Zielinska *et al.* (2018) reported lower moisture content in microwave pre-treated samples compare to control. Higher levels of moisture could lead to microbial spoilage and subsequent deterioration in quality. Sabry *et al.* (2016) reported variations in moisture content of the dried carrot powder due to microwave treatments. Water loss during microwave pre-treatments increased with increase in microwave power and time.

*Effect of pressing:*Further, it was observed that mean moisture (P) of the carrot powder when dehydrated followed by pressing treatment varied significantly from 6.15 to 7.27 %, with minimum moisture (6.15 %) in carrot powder when dehydrated followed by pressing treatment (P_2) and maximum moisture (7.27 %) in carrot powder when dehydrated without pressing treatment (P_1). The lower moisture in carrot powder prepared pressing treatment might be attributed to release of most of water from the tissue due to pressing and higher dehydration rate for left over carrot pomace which requires dehydration time for drying. Earlier studies also observed similar results for moisture in treatments which requires less dehydration time for okra, cauliflower and onions (Anon., 2017). Lower moisture and water activity was also observed in food products which requires less dehydration time as reported by Vaghashiya (2016) in dehydrated *Aloe vera* gel and Zinzala (2019) for bael candy.

*Effect of storage:*Storage of the carrot powder for six months resulted significant increase in moisture (S) from initial value of 5.35to 7.80 %. Al-Amin *et al.* (2015) also observed increase in moisture content of dried carrot slices (5mm) when dried by mechanical as well as solar drying methods. Chukwu and Lawal (2015) reported that moisture content of sweet potato flour increased from 4.32 to 5.36 % within first week of storage but decreased to 5.27 % at the end of two weeks storage period and attributed this to loss of moisture during storage. Alinnor and Akalezi (2014) reported that the dehydrated flour can be stored successfully during storage if the moisture content of flour is below 8.3 %. Maneepun*et al.* (1992) reported increased the moisture content of sweet potato flour upto 8 % in four and a half months. During storage, gain in moisture content in potato flour also reported by

Kulkarni *et al.* (1993). Raj *et al.* (2011) registered moisture content increase in potato flour of different cultivars from 3.07 to 4.78 per cent during storage period of six months. Sra *et al.* (2014) reported that moisture content of dried carrot slices increased from 6.3 to 8.4 %. Abano *et al.* (2011) reported that KMS pre-treated samples performed better in terms of moisture diffusivity at all drying temperatures. Tiwari and Sarkar (2018) reported 87.02 % moisture content in fresh carrot and 4.2 % in dried carrot powder. Ramachandra and Rao (2011) also reported gradual increase in moisture content of dehumidified air-dried *Aloe vera* gel powder during accelerated storage. Sharada (2013) also reported gradual increase in moisture content of foam mat dried guava and banana powder during storage. The increase in moisture during storage period of six months might be attributed to increase in relative humidity in the atmosphere due to continuations of rainy monsoon and due to permeability of packaging materials to water vapours. The similar reason for other processed products had been reported by Raj *et al.* (2009) for dehydrated onion rings.

*Effect of treatment interactions:*Interaction of preparation techniques, microwave pre-treatment, pressing and storage (TMPS) depicted variation in moisture of carrot powder from 4.15 to 10.41 %, with minimum increase of moisture from 4.15 to 5.85 % ($T_2M_3P_2S_1$ to $T_2M_3P_2S_4$) in powder which was prepared by dehydrating crushed materials by giving microwave for 60 seconds followed by pressing and maximum increase of moisture from 7.30 to 10.41% ($T_3M_1P_1S_1$ to $T_3M_1P_1S_4$) in carrot powder which was prepared by dehydrating carrot slices without microwave and pressing pre-treatment. Interactions of TxM, TxP, MxP, TxMxP, TxS, MxS, PxS, TxMxS, TxPxS, MxPxS, TxMxPxS were found to have significant effect.

β-carotene

The perusal of data pertaining to effect of different treatments on beta carotene of carrot powder during six months storage period has been presented in Table 6.

*Effect of preparation techniques:*Among different preparation techniques (T), the beta carotene of carrot powder varied significantly between 105.91 and 124.72 mg/100g, with minimum beta carotene (105.91 mg/100g) in carrot powder which was prepared by giving crushing treatment (T_2) and maximum beta carotene (124.72 mg/100g) in slicing (T_3). The food commodity having smaller size possess large surface area can release most of the soluble solids along with water. The crushing treatment observed minimum beta carotene in carrot powder which might be attributed to release of large amount soluble solids along with water in the form of juice and thus less beta carotene remained in the dried carrot powder due to pressing treatment.Tadesse *et al.* (2015) reported the highest β-carotene (74.97 ppm) for combination of the samples blanched at 55^{o}C and soaked in 5% salt solutions. Alam *et al.* (2013) reported maximum β-carotene (633.57 µg 100 g^{-1}) value for citric acid blanching (CB) pre-treated samples of carrot pomace followed by solar dried and the minimum value (186.01 µg 100 g^{-1}) for CB pre-treated samples followed by sun dried.
*Effect of microwave pre-treatment:*Data shows that among different microwave pre-treatments grand mean beta carotene (M) of microwave pre-treated carrot powder varied significantly between 112.32 and 117.55 mg/100g, with maximum beta carotene (117.55 mg/100g) in carrot powder pre-treated with microwave for 60 seconds (M_3) and minimum beta carotene (112.32 mg/100g) in carrot powder prepared without microwave pre-treatment (M_1). Sabry *et al.* (2016) reported similar variations in beta carotene content of the dried carrot powder due to microwave treatments and higher beta carotene content was observed in the samples treated with microwave as compared to without microwave. Cui *et al.* (2004) also reported higher beta carotene content in dried carrot slices and Chines chive leaves when

given microwave treatment. Arjmandi*et al*. (2016) reported increase in phenolics and lycopene contents in smoothie due to microwave treatment.

*Effect of pressing:*Further, it was observed that mean Beta carotene (P) of the carrot powder when dehydrated followed by pressing treatment varied significantly from 100.47 to 128.73 mg/100g, with minimum beta carotene 100.47 mg/100 g in carrot powder when dehydrated followed by pressing treatment (P_2) and maximum beta carotene 128.73 mg/100g in carrot powder when dehydrated without pressing treatment (P_1). The food commodity having smaller size possess large surface area can release most of the soluble solids along with water due to pressing. The pressing treatment observed minimum beta carotene in carrot powder which might be attributed to release of large amount soluble solids along with water in the form of juice and thus less beta carotene remained in the dried carrot powder due to pressing treatment.

*Effect of storage:*Storage of the carrot powder for six months resulted significant decrease in beta carotene (S) from initial value of 157.29to 59.53 mg/100g. Hal (2007) reported that during storage, auto-oxidation of carotenoids may take place, leading to a loss of color and an undesirable decline in beta-carotene value. The stability of beta-carotene proved to be strongly and adversely affected by storage temperature and light. Chaturvedi *et al.* (2013) reported that carotenoids content decreased during storage from 59.8 per cent to 52 per cent of β-carotene after six months of storage.Sra*et al.* (2014) reported decrease in the β-carotene content from 69.4 to 49.2 mg/100 g during storage. Carrot slices pre-treated with 6% KMS and packed in AFL pouches were found to retain highest carotene content. Singh *et al.* (2013) reported that the pressure-cooking treatment utilized for the preparation of carrot powder and grits revealed that carrot powder had higher β-carotene levels (36.94 mg/100 g) than carrot grits (33.48 mg/100 g) which further showed a gradual loss of β-carotene during storage in all the packaging materials but higher β-carotene content reported to be retained in the aluminium laminated pack and can be stored safely up to 6 months at room temperature. Similar decrease in ß-carotene content (S) from initial value of 17.53 mg/100g to 9.84 mg/100g observed during in six months storage of the sweet potato flour by Ashuqullah (2017).

*Effect of treatment interactions:*Interaction of preparation techniques, microwave pre-treatment, pressing and storage (TMPS) depicted variation in beta carotene of carrot powder from 42.16 to 177.28 (mg/100g), with minimum decrease of beta carotene from 144.90 to 54.80 mg/100g ($T_2M_3P_2S_1$ to $T_2M_3P_2S_4$) in powder which was prepared by dehydrating crushed materials by giving microwave for 60 seconds followed by pressing and maximum decrease of beta carotene from 171.87 to 50.55 mg/100g ($T_3M_1P_1S_1$ to $T_3M_1P_1S_4$) in carrot powder which was prepared by dehydrating carrot slices without microwave and pressing pre-treatment. Interactions of TxM,TxP, MxP, TxMxP, TxS, MxS, PxS, TxMxS, TxPxS, MxPxS, TxMxPxS were found to have significant effect.

Overall acceptability

The perusal of data pertaining to effect of different treatments on overall acceptability of carrot powder during six months storage period has been presented in Table 7.

*Effect of preparation techniques:*Among different preparation techniques (T), the overall acceptability (9 point Hedonic scale) of carrot powder varied significantly between 6.25 and 7.56, with maximum overall acceptability (7.56) in carrot powder which was prepared by giving crushing treatment (T_2) and minimum overall acceptability (6.25) in shredding (T_1). Nath *et al*. (2012) reported variations in taste in ginger candy when prepared using different slice thickness (5-25 mm) and blanched for different time (10-30 min).The higher overall acceptability in carrot powder prepared using crushing treatment followed by pressing might be attributed to higher dehydration rate and requirement of less dehydration time for drying. Earlier studies also observed similar results for overall acceptability in treatments which requires less dehydration time for okra, cauliflower and onions (Anon. 2017). Higher overall acceptability was also observed in food products which requires less dehydration time as reported by Zinzala (2019) for bael candy. The higher overall acceptability scorein carrot powder which was prepared by giving crushing treatment attributed to retention of more colour, taste, flavor and texture in dehydrated powder. Chaturvedi *et al.* (2013) reported variations in overall acceptability in dehydrated carrots using different pre-treatments and drying techniques i.e., tray dried (TD), tray dried and radiated (TDR), Infra-red dried (IR), Infra-red dried and radiated (IRR). They reported maximum overall acceptability value (4.93) in IRR and lowest value (4.17) in TD. Kukanoor*et al.* (2014) reported highest value (4.46) of texture and overall acceptability (4.55) in the dehydrated carrot slices blanched for 2 minutes and steeped in 300 brix syrup followed by 6% salt for 2 hours. Whereas, Raj et al (2009) reported significance variations in overall acceptability of the potato flours of the varieties due to variations in the NEB, sensory colour and texture score and these scores of the product directly correlated with the overall acceptability of the product.

*Effect of microwave pre-treatment:*Data shows that among different microwave pre-treatments grand mean overall acceptability (M) of microwave pre-treated carrot powder varied significantly between 6.56 and 7.04, with maximum overall acceptability (7.04) in carrot powder pre-treated with microwave for 60 seconds (M_3) and minimum overall acceptability (6.56) in carrot powder prepared without microwave pre-treatment (M_1). Pandit (2015) reported similar variations in overall acceptability of dehydrated elephant foot yam due to variation of microwave exposure time and power. This can be explained by the high internal pressure produced by microwave heating which can cause structure of carrot slices to expand and puff during dehydration which provide more porous structure in the food product. Zielinska *et al.* (2018) also reported improvement in colour due to microwave treatment in dried cranberries.

*Effect of pressing:*Further, it was observed that mean overall acceptability (P) of the carrot powder when dehydrated followed by pressing treatment varied significantly from 6.59 to 7.00, with maximum overall acceptability (7.00) in carrot powder when dehydrated followed by pressing treatment (P_2) and minimum overall acceptability (6.59) in carrot powder when dehydrated without pressing treatment (P_1). The higher overall acceptability in carrot powder prepared using pressing treatment might be attributed to higher dehydration rate and requirement of less dehydration time for drying.

*Effect of storage:*Storage of the carrot powder for six months resulted significant decrease in overall acceptability (S) from initial value of 7.31to 6.09. The decrease in overall acceptability score might be attributed to increase in moisture content, water activity and NEB in dehydrated carrot powder during storage. Sra *et al.* (2014) reported decrease in overall acceptability dried carrot slices from 8.2 to 7.1 during six months storage period. Chaturvedi *et al.* (2013) reported decrease in overall acceptability in dehydrated carrots during six months of storage. Pandit (2015) reported similar variations in overall acceptability of dehydrated elephant foot yam due to variation of microwave exposure time and power during six months storage. This can be explained by the high internal pressure produced by microwave heating which can cause structure of carrot slices to expand and puff during dehydration which provide more porous structure in the food product. Similar results were obtained by Sunjka*et al.* (2004) in cranberries.

Effect of treatment interactions: Interaction of preparation techniques, microwave pre-treatment, pressing and storage (TMPS) depicted variation in overall acceptability of carrot powder from 4.81 to 8.65, with minimum decrease of overall acceptability from 8.65 to 7.78 ($T_2M_3P_2S_1$ to $T_2M_3P_2S_4$) in powder which was prepared by dehydrating crushed materials by giving microwave for 60 seconds followed by pressing and maximum decrease of overall acceptability from 6.95 to 5.15 ($T_3M_1P_1S_1$ to $T_3M_1P_1S_4$) in carrot powder which was prepared by dehydrating carrot slices without microwave and pressing pre-treatment. Interactions of TxM,TxP, MxP, TxMxP, TxS, MxS, PxS, TxMxS, TxPxS, MxPxS, TxMxPxS were found to have significant effect.

CONCLUSION

It can be concluded that carrot powder prepared by dehydrating crushed materials by giving microwave pre-treatment for 60 seconds followed by pressing (after single strength juice extraction) can remain safe for six months in PP bags (400 gauge) with minimum changes in chemical and sensory quality. This technique possess additional benefit of preparing two products simultaneously i.e. juice and powder instead of product either alone. Thus, the developed technologies can commercially be explored by food processing industry. Therefore, profitable utilization of carrot grown in India by processing can ensure better returns to the growers, processors and consumers.

REFERENCES

Abano, E. E.; Ma, H. and Qu, W. (2011). Effects of pretreatments on the drying characteristics and chemical composition of garlic slices in a convective hot air dryer. *J Agric. Food Tech.*, **1** (5): 50-58.

Alam, M. S.; Gupta, K.; Khaira, H. and Javed, M. (2013). Quality of dried carrot pomace powder as affected by pretreatments and methods of drying. *Agril.Eng. International:CIGR Journal*, **15** (4): 236-243.

Alinnor, I.J. and Akalezi, C.O. (2014). Proximate and Mineral Compositions of *Dioscorea rotundata*. *American Journal Research Communication*, **2** (3) 119 – 126.

Amerine, M.A.; Pangborn, R.M. and Roessler, E.B. (1965). Principles of sensory evaluation of food. Acad. Press, New York: Academic Press. 250.

AOAC. (1984). Official methods of analysis, *Association of Official Analytical Chemists*. 14th edn., Arlington, Virginia, USA.

Arjmandi, M.; Oton, M.; Artés-Hernandez, F.; Gomez, P. A.; Artes, F. and Aguayo, E. (2016). Effect of microwave treatments on the quality of a smoothie. In VIII International Postharvest Symposium: Enhancing Supply Chain and Consumer Benefits-Ethical and Technological Issues 1194 (pp. 1481-1486).

Ashuqullah (2017). Evaluation of sweet potato {*Ipomoea batatas* (L.) Lam} varieties and pre-treatments for dehydration into flour. M.Sc. Thesis, Navsari Agricultural University, Navsari, Gujarat, India.

Chaturvedi, A.; Sujatha, V.; Ramesh, C. and Babu, J. D. (2013). Development of shelf stable intermediate moisture carrot (Daucus carota) shreds using radiation as hurdle technology. *Int. Food Res. J.*, **20** (2): 775.

Chukwu, O., and Lawal, A. O. (2015). Comparative study of storage stability of Sweet Potato and Yam flours. *International Journal of Emerging Technologies in Engineering Research*, **3** (3): 44-49.

Dede, S.; Alpas, H. and Bayındırlı, A. (2007). High hydrostatic pressure treatment and storage of carrot and tomato juices: Antioxidant activity and microbial safety. *J. Sci. Food and Agri.*, **87** (5): 773-782.

Dinrifo, R. R. (2012). Effects of pre-treatments on drying kinetics of sweet potato slices. *Agricultural Engineering International Journal*, **14** (3): 136-145.

Gopalan, C.; Shastri, R. B. and Balasubramanian, S. C. (2004). Nutritive value of Indian foods. National Institute of Nutrition. Ind. Council of Medical Res., Hyderabad. 32-67.

Hatamipour, M. S.; Kazemi, H. H.; Nooralivand, A., and Nozarpoor, A. (2007). Drying characteristics of six varieties of sweet potatoes in different dryers. Journal of Food and Bio Products Processing, **85** (3):171-177.

Jabbar, S.; Abid, M.; Hu, B.; Wu, T.; Hashim, M. M.; Lei, S. and Zeng, X. (2013). Quality of carrot juice as influenced by blanching and sonication treatments. *LWT-Food Sci. and Tech.*, **55** (1): 16-21.

Kalse, S. B.; Patil, M. M. and Jain, S. K. (2012). Microwave drying of onion slices. *Res. J. Chemical Sci.*,**2** (4): 57-60.

Kaur, K. and Singh, A. K. (2014). Drying kinetics and quality characteristics of beetroot slices under hot air followed by microwave finish drying. *African J. Agril. Res.*, **9** (12): 1036-1044.

Khan, M. R. (2012). Osmotic dehydration technique for fruits preservation-a review. *Pak. J. Food. Sci.*, **22** (2): 71-85.

Kukanoor, L.; Karadiguddi, M.; Rayar, S. and Jaishankar, H. P. (2014). Effect of pre-treatments on physical and sensory qualities of dehydrated carrot slices. *J. Hort.*, **1**(3): 1-3.

Kumar, N., and Kumar, K. (2011). Development of carrot pomace and wheat flour based cookies. *J. of Pure and App. Sci. and Tech.*, **1**(1): 5-11.

Leeratanarak, N., Devahastin, S., and Chiewchan, N. (2006).Drying kinetics and quality of potato chips undergoing different drying techniques. *Journal of Food Engineering*, **77** (3):635-643.

Loesecke, V and Willard, H. 1955. Drying and dehydration of foods. *Reinhold Publishing Corporation*: 283-291.

Maneepun, S.S., Reungmaneepaitoon, and M. Yunchalad. 1992. Product development for root and tuber crops, Vol I –Asia (G. J. Scott, S. Wiersema, and P. I. Ferguson, eds.), CIP, Lima: 229.

Maskan, M. (2001). Kinetics of colour change of kiwifruit during hot air and microwave drying. *J. Food Eng.*, 48.

Pandit, P. D., (2015) Microwave assisted convective drying characteristics of elephant foot yam [*Amorphalluspaeoniifolius* (Densst.) NICOLSON] *Thesis. M.Sc. (Agri.),* Navsari Agricultural University, Navsari, India. pp. 87-91.

Panse, V. G., and Sukhatme, P. V. (1967). *Statistical methods for research workers.* ICAR publication, New Delhi, pp. 20-40.

Raj, D.; Huddar, A. G. and Gupta, P. (2004). Effect of dehydration temperatures on the quality characteristics of dehydrated onion rings during storage. *Udyanika J. Horti. Sci.*, **10** (4): 47-52.

Raj, D.; Huddar, A. G.; Subanna, V. C. and Gowda, I. N. D. (2009). Effect of packaging on the quality characteristics of dehydrated onion rings during storage. *Beverages Fd. World*, **36** (5): 33-35.

Raj, D.; Lal, B. B. and Joshi, V. K. (2011). Yield, quality and storability of the potato flour of different Indian cultivars. *Int. J. Fd. Fermentation*, **1**(1): 111-117.

Ranganna, S. (1997). *Handbook of Analysis and Quality Control for Fruit and Vegetable Products*. Tata McGraw Hill Publishing Co. Ltd., New Delhi (India). pp. 7-12.

Rayman, A. and Baysal, T. (2011). Yield and quality effects of electroplasmolysis and microwave applications on carrot juice production and storage. *J. Food Sci.*, **76** (4): C598-C605.

Sabry, Z. A.; Bahlol, H. E.; El-Desouky; A. I. and Assous, M. T. M. (2016). Effect of microwave pretreatment and drying methods on the carrot powder quality. *Middle East J. App. Sciences*, **6** (2): 349-356.

Sharada, S. (2013). Studies on effect of various operating parameters & foaming agents-Drying of fruits and vegetables. *Inter. J. Modern Engin. Res.*, **3**(3): 1512-1519.

Shivhare U. S.; Gupta M.; Basu S. and Raghavan G.S.V. (2009). Optimization of blanching process for carrots. *J. Food. Process. Eng.*,**3** (2):587-605.

Singh, P.; Kulshrestha, K., and Kumar, S. (2013). Effect of storage on β-carotene content and microbial quality of dehydrated carrot products. *Food Biosci.*, **2**, 39-45.

Sra, S. K.; Sandhu, K. S. and Ahluwalia, P. (2014). Effect of treatments and packaging on the quality of dried carrot slices during storage. *J. food sci. technol*., **51** (4): 645-654.

Tadesse, T. F.; Abera, S. and Worku, S. (2015). Nutritional and sensory properties of solar-dried carrot slices as affected by blanching and osmotic pre-treatments. *Int. J. Food Sci. and Nutrition Eng.*, **5** (1): 24-32.

Tiwari, S., and Sarkar, N. (2018). Development and evaluation of carotene rich carrot powder. *Int. J. Res. Biosci. Agric. Tech.*, **6** (1): 123-131.

Vaghashiya, J. M.; Raj, D.; Bhanderi, D. R.; Desai, C. S. and Patel, J. M. (2016). Health drink preparation using *Aloe vera*, bitter gourd, aonla and guava. *Green Farming*. **7**(6): 1486-1490.

Wilczyński, K.; Kobus, Z. and Dziki, D. (2019). Effect of press construction on yield and quality of apple juice. Sustainability, **11** (13): 3630.

Zielinska, M.; Zielinska, D. and Markowski, M. (2018). The effect of microwave-vacuum pretreatment on the drying kinetics, color and the content of bioactive compounds in osmo-microwave-vacuum dried cranberries (*Vaccinium macrocarpon*). *Food and Bioprocess Tech.*, **11** (3): 585-602.

Zinzala, P. B. (2019) Processing and value addition of Bael (*Aegle marmelos* L.). *Thesis Ph.D.*, Navsari Agricultural University, Navsari, India.

Table 2: Effect of preparation techniques, microwave pre-treatment and pressing on the dehydrated powder yield of carrot (10 kg tray load) during preparation of powder

Storage Intervals(S)	Preparation techniques (T)	Pressing (P)								
		P_1: Without pressing - (Control)				P_2: Pressing				Grand Mean (T)
		Microwave pre-treatment (M)				Microwave pre-treatment (M)				
		M_1: control	**M_2:** 30 S	**M_3:** 60 S	**Mean**	**M_1:** control	**M_2:** 30 S	**M_3:** 60 S	**Mean**	
Powder yield (%)	**T_1:** Shredding	11.97	11.43	11.51	**11.64**	9.47	8.60	7.80	**8.62**	10.13
	T_2: Crushing	11.58	11.41	11.38	**11.46**	7.26	6.70	6.20	**6.72**	9.09
	T_3: Slicing	12.92	12.51	12.16	**12.53**	12.53	12.23	11.93	**12.23**	12.38
	Mean (M, P of S_1)	**12.16**	**11.78**	**11.68**	**11.87**	**9.75**	**9.18**	**8.64**	**9.19**	
Grand Mean		**10.96**	**10.48**	**10.16**						
			S.Em. ±	**$CD_{0.05}$**		**S.Em. ±**	**$CD_{0.05}$**			
		T	0.042	0.121	**T_XP**	0.060	0.171			
		M	0.042	0.121	**MxP**	0.060	0.171			
		P	0.034	0.099	**T_XM_XP**	0.103	0.297			
		T_XM	0.073	0.210						
		CV%				1.70				

Table 3: Effect of preparation techniques, microwave pre-treatment and pressing on the dehydration rate of carrot (10 kg tray load) during preparation of powder

Storage Intervals(S)	Preparation techniques (T)	Pressing (P)								Grand Mean (T)
		P_1: Without pressing - (Control)				P_2: Pressing				
		Microwave pre-treatment (M)				Microwave pre-treatment (M)				
		M_1: control	M_2: 30 S	M_3: 60 S	Mean	M_1: control	M_2: 30 S	M_3: 60 S	Mean	
Dehydration rate (g/min)	T_1: Shredding	8.88	8.97	9.08	**8.98**	7.04	6.76	6.15	**6.65**	7.81
	T_2: Crushing	8.38	8.55	8.62	**8.52**	5.24	5.00	5.54	**5.26**	6.89
	T_3: Slicing	7.97	8.02	8.07	**8.02**	8.04	8.08	9.49	**8.54**	8.28
	Mean (M, P of S_1)	**8.41**	**8.51**	**8.59**	**8.50**	**6.77**	**6.61**	**7.06**	**6.82**	
Grand Mean		**7.59**	**7.56**	**7.83**						
			S.Em. ±	**$CD_{0.05}$**		**S.Em. ±**	**$CD_{0.05}$**			
		T	0.060	0.172	**TxP**	0.085	0.243			
		M	0.060	0.172	**MxP**	0.085	NS			
		P	0.049	0.140	**TxMxP**	0.147	0.421			
		T_X M	0.104	0.298						
		CV %	3.32							

Table 4: Effect of preparation techniques, microwave pre-treatment and pressing on the rehydration ratio of carrot of powder

Storage Intervals (S)	Preparation techniques (T)	Pressing (P)								Grand Mean (T)
		P_1: Without pressing - (Control)				P_2: Pressing				
		Microwave pre-treatment (M)				Microwave pre-treatment (M)				
		M_1:control	M_2: 30 S	M_3: 60 S	Mean	M_1:control	M_2:30 S	M_3:60 S	Mean	
Rehydration ratio	**T_1:** Shredding	5.31	5.42	5.74	**5.49**	6.27	6.58	6.98	**6.61**	6.05
	T_2: Crushing	6.12	6.33	6.7	**6.38**	6.48	6.58	7.11	**6.72**	6.55
	T_3: Slicing	4.39	4.55	4.84	**4.59**	4.65	4.81	5.12	**4.86**	4.73
	Mean (M, P of S_1)	**5.27**	**5.43**	**5.76**	**5.49**	**5.80**	**5.99**	**6.40**	**6.06**	
Grand Mean		**5.54**	**5.71**	**6.08**						
			S.Em. ±	**$CD_{0.05}$**		**S.Em. ±**	**$CD_{0.05}$**			
		T	0.035	0.100	**TxP**	0.049	0.141			
		M	0.035	0.100	**MxP**	0.049	NS			
		P	0.029	0.082	**TxMxP**	0.086	NS			
		TxM	0.060	NS						
		CV%	2.56							

Table 5: Effect of preparation techniques, microwave pre-treatment and pressing on the moisture content (%) of carrot powder during storage

Storage Intervals(S)	Preparation techniques (T)	Pressing (P)								Grand Mean (S, TS)	Grand Mean (T)
		P_1: Without pressing - (Control)				P_2: Pressing					
		Microwave pre-treatment (M)				Microwave pre-treatment (M)					
		M_1:control	M_2: 30 S	M_3: 60 S	Mean (P_1, S)	M_1:control	M_2: 30 S	M_3: 60 S	Mean (P_2, S)		
S_1: Initial	T_1: Shredding	5.98	5.82	5.46	5.75	4.97	4.65	4.44	4.69	5.22	**6.69**
	T_2: Crushing	5.63	5.52	5.45	5.53	4.53	4.42	4.15	4.37	4.95	**5.91**
	T_3: Slicing	7.30	6.24	5.71	6.42	5.82	5.35	4.85	5.34	5.88	**7.53**
	Mean (MP of S_1)	**6.30**	**5.86**	**5.54**	**5.90**	**5.11**	**4.81**	**4.48**	**4.80**	**5.35**	
S_2:2 Months	T_1: Shredding	7.62	7.46	7.10	7.39	6.61	6.04	5.94	6.20	6.80	
	T_2: Crushing	6.27	6.16	6.09	6.17	5.67	5.36	5.19	5.41	5.79	
	T_3: Slicing	8.94	7.88	7.35	8.06	7.46	6.99	6.49	6.98	7.52	
	Mean (MP of S_2)	**7.61**	**7.17**	**6.85**	**7.21**	**6.58**	**6.13**	**5.87**	**6.19**	**6.70**	
S_3:4 months	T_1: Shredding	7.86	7.70	7.34	7.63	6.85	6.28	6.18	6.44	7.04	
	T_2: Crushing	6.51	6.40	6.33	6.41	5.71	5.57	5.33	5.54	5.98	
	T_3: Slicing	9.18	8.12	7.59	8.30	8.70	7.23	6.73	7.55	7.93	
	Mean (MP of S_3)	**7.85**	**7.41**	**7.09**	**7.45**	**7.09**	**6.36**	**6.08**	**6.51**	**6.98**	
S_4:6 months	T_1: Shredding	8.80	8.23	7.93	8.32	7.22	7.13	6.88	7.08	7.70	
	T_2: Crushing	7.85	7.78	7.63	7.75	6.27	6.12	5.86	6.08	6.92	
	T_3: Slicing	10.41	9.65	8.27	9.44	8.88	8.18	7.34	8.13	8.79	
	Mean (MP of S_4)	**9.02**	**8.55**	**7.94**	**8.51**	**7.46**	**7.14**	**6.69**	**7.10**	**7.80**	
Grand Mean (P)		**7.70**	**7.25**	**6.85**	**7.27**	**6.56**	**6.11**	**5.78**	**6.15**		
Grand Mean (M)		**7.13**	**6.68**	**6.32**							

	S.Em. ±	$CD_{0.05}$		S.Em. ±	$CD_{0.05}$		S.Em. ±	$CD_{0.05}$		S.Em. ±	$CD_{0.05}$
T	0.021	0.061	**T_XP**	0.030	0.086	**S**	0.025	0.071	**TxMxS**	0.076	0.213
M	0.021	0.061	**MxP**	0.030	0.086	**TxS**	0.044	0.123	**TxPxS**	0.062	0.174
P	0.017	0.049	**TxMxP**	0.052	0.148	**MxS**	0.044	0.123	**MxPxS**	0.062	0.174
T_XM	0.037	0.105				**PxS**	0.036	0.100	**TxMxPxS**	0.107	0.301
CV %	2.67					**CV %**	2.77				

Table 6: Effect of preparation techniques, microwave pre-treatment and pressing on the β- carotene (mg/100g) of carrot powder during storage

Storage Intervals(S)	Preparation techniques (T)	Pressing (P)									
		P_1: Without pressing - (Control)				P_2: Pressing				Grand Mean (S, TS)	Grand Mean (T)
		Microwave pre-treatment (M)				Microwave pre-treatment (M)					
		$M_{1:}$control	$M_{2:}$ 30 S	$M_{3:}$ 60 S	Mean (P_1, S)	$M_{1:}$control	$M_{2:}$ 30 S	$M_{3:}$ 60 S	Mean (P_2, S)		
S_1: Initial	T_1: Shredding	175.95	177.43	178.04	177.14	139.18	133.52	120.67	131.12	154.13	**118.63**
	T_2: Crushing	177.28	178.45	180.13	178.62	111.13	104.81	114.90	110.28	144.45	**105.91**
	T_3: Slicing	171.87	170.44	178.40	173.57	171.11	171.11	176.82	173.01	173.29	**124.72**
	Mean (MP of S_1)	**175.03**	**175.44**	**178.86**	**176.44**	**140.47**	**136.48**	**137.46**	**138.14**	**157.29**	
S_2:2 Months	T_1: Shredding	154.33	155.86	156.47	155.55	114.09	117.25	110.03	113.79	134.67	
	T_2: Crushing	155.70	156.88	158.56	157.05	80.61	92.11	101.13	91.28	124.17	
	T_3: Slicing	150.30	148.87	156.77	151.98	149.48	148.41	155.24	151.04	151.51	
	Mean (MP of S_2)	**153.44**	**153.87**	**157.27**	**154.86**	**114.73**	**119.26**	**122.13**	**118.71**	**136.78**	
S_3:4 months	T_1: Shredding	116.48	117.96	118.63	117.69	88.16	89.74	95.38	91.09	104.39	
	T_2: Crushing	117.81	118.98	120.72	119.17	70.85	72.87	77.01	73.58	96.37	
	T_3: Slicing	112.40	110.98	118.93	114.10	111.64	110.52	117.40	113.19	113.65	
	Mean (MP of S_3)	**115.56**	**115.97**	**119.43**	**116.99**	**90.22**	**91.04**	**96.60**	**92.62**	**104.80**	
S_4:6 months	T_1: Shredding	67.58	69.05	69.72	68.78	42.45	52.97	55.23	50.22	59.50	
	T_2: Crushing	68.90	70.07	71.81	70.26	44.20	42.16	54.80	47.05	58.66	
	T_3: Slicing	50.55	62.12	70.02	60.90	53.73	61.61	64.49	59.94	60.42	
	Mean (MP of S_4)	**62.34**	**67.08**	**70.52**	**66.65**	**46.79**	**52.25**	**58.17**	**52.40**	**59.53**	
Grand Mean (P)		**126.60**	**128.09**	**131.52**	**128.73**	**98.05**	**99.76**	**103.59**	**100.47**		
Grand Mean (M)		**112.32**	**113.92**	**117.55**							

	S.Em. ±	**$CD_{0.05}$**		**S.Em. ±**	**$CD_{0.05}$**		**S.Em. ±**	**$CD_{0.05}$**		**S.Em. ±**	**$CD_{0.05}$**
T	0.405	1.161	**T_XP**	0.572	1.641	**S**	0.512	1.436	**TxMxS**	1.537	4.309
M	0.405	1.161	**MxP**	0.572	1.641	**TxS**	0.887	2.488	**TxPxS**	1.255	3.518
P	0.330	0.947	**TxMxP**	0.991	2.842	**MxS**	0.887	2.488	**MxPxS**	1.255	3.518
T_XM	0.171	0.490				**PxS**	0.725	2.031	**TxMxPxS**	2.174	6.094
CV %	3.02					**CV %**	3.31				

Table 7: Effect of preparation techniques, microwave pre-treatment and pressing on the sensory overall acceptability (9-point Hedonic scale) of carrot powder during storage

Storage Intervals(S)	Preparation techniques (T)	Pressing (P)									
		P_1: Without pressing - (Control)				P_2: Pressing				Grand Mean (S, TS)	Grand Mean (T)
		Microwave pre-treatment (M)				Microwave pre-treatment (M)					
		M_1: control	M_2: 30 S	M_3: 60 S	Mean (P_1, S)	M_1: control	M_2: 30 S	M_3: 60 S	Mean (P_2, S)		
S_1: Initial	**T_1**: Shredding	6.20	6.75	6.85	6.60	6.88	6.75	7.00	6.88	6.74	**6.25**
	T_2: Crushing	7.30	7.95	7.95	7.73	8.15	8.35	8.65	8.38	8.06	**7.56**
	T_3: Slicing	6.95	7.00	7.18	7.04	7.10	7.10	7.40	7.20	7.12	**6.59**
	Mean (MP of S_1)	**6.82**	**7.23**	**7.33**	**7.13**	**7.38**	**7.40**	**7.68**	**7.49**	**7.31**	
S_2:2 Months	**T_1**: Shredding	5.85	6.40	6.75	6.33	6.70	6.40	6.65	6.58	6.46	
	T_2: Crushing	6.95	7.60	7.70	7.42	7.80	8.00	8.25	8.02	7.72	
	T_3: Slicing	6.70	6.85	6.90	6.82	6.60	6.75	7.20	6.85	6.83	
	Mean (MP of S_2)	**6.50**	**6.95**	**7.12**	**6.86**	**7.03**	**7.05**	**7.37**	**7.15**	**7.00**	
S_3:4 months	**T_1**: Shredding	5.58	6.13	6.48	6.06	6.93	6.13	6.38	6.48	6.27	
	T_2: Crushing	6.68	7.33	7.58	7.19	7.53	7.73	8.03	7.76	7.48	
	T_3: Slicing	6.43	6.58	6.63	6.54	6.83	6.48	6.93	6.74	6.64	
	Mean (MP of S_3)	**6.23**	**6.68**	**6.89**	**6.60**	**7.09**	**6.78**	**7.11**	**6.99**	**6.79**	
S_4:6 months	**T_1**: Shredding	4.81	5.40	5.58	5.26	5.63	5.70	6.03	5.78	5.52	
	T_2: Crushing	6.01	6.72	6.87	6.53	7.07	7.39	7.78	7.41	6.97	
	T_3: Slicing	5.15	5.63	5.92	5.57	5.70	5.87	6.33	5.96	5.76	
	Mean (MP of S_4)	**5.32**	**5.92**	**6.12**	**5.79**	**6.13**	**6.32**	**6.71**	**6.39**	**6.09**	
Grand Mean (P)		**6.22**	**6.69**	**6.86**	**6.59**	**6.91**	**6.89**	**7.22**	**7.00**		
Grand Mean (M)		**6.56**	**6.79**	**7.04**							

	S.Em. ±	$CD_{0.05}$		S.Em. ±	$CD_{0.05}$		S.Em. ±	$CD_{0.05}$		S.Em. ±	$CD_{0.05}$
T	0.021	0.059	**T_XP**	0.029	0.084	**S**	0.026	0.073	**TxMxS**	0.079	0.220
M	0.021	0.059	**MxP**	0.029	0.084	**TxS**	0.045	0.127	**TxPxS**	0.064	0.180
P	0.017	0.049	**TxMxP**	0.051	0.145	**MxS**	0.045	0.127	**MxPxS**	0.064	0.180
T_XM	0.036	0.103				**PxS**	0.037	0.104	**TxMxPxS**	0.111	0.312
CV %	2.59					**CV %**	2.84				