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Optimization of process protocol for the development of anthocyanin enriched ginger candy

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Abstract
Ginger is one of the principal spice and important cash crop of India and abroad gaining importance in food, pharmaceutical and chemical industries due to the presence of several bioactive compounds. The characteristic flavour of ginger is due to the presence of polyphenol compounds like gingerol, zingiberone, bisabolene, paradols, shogaols and gingerones which possess therapeutic properties and also stimulates digestion, absorption, relieve constipation and flatulence. Ginger candy is a traditionally ready to eat intermediate moisture food (IMF) product having a great demand in confectionary industry due to the acceptable sensorial characteristics and appreciable nutrients especially phenols. In the conventional method of ginger candy preparation, honey may be an effective replacement for sugar which is generally used as a sweetener. The optimized method for preparation of anthocyanin enriched ginger candy (plum pulp and honey) involves 7.5mm slice thickness, blanching in 1.0 per cent lime juice, osmotic dip in 70 ^{o}B immersion solution (plum pulp and honey) for 5 hours and drying in a mechanical dehydrator (55±2 ^{o}C). The high concentration of fructose and glucose in honey resulted in increased rate of mass transfer other than being a source of natural antioxidants. Nutritionally anthocyanin enriched ginger candy prepared by dipping in hypertonic solution containing plum pulp and honey possessed appreciable amount of anthocyanin (56.64 mg/100g), ascorbic acid (17.46 mg/100g), total phenols (26.95 mg/100g) and antioxidant activity (97.66 %).

Keywords: candy, honey, plum, anthocyanin enrichment, organoleptic quality

Introduction
Ginger (*Zingiber officinale Roscoe*), a versatile rhizome belonging to family Zingiberaceae, is a native plant of Asia which is also cultivated in West Indies, Africa and many other tropical countries of the world (Singletary, 2010) [20]. It is very popular spice used in number of food and beverages and is valued due to the aromatic compounds which give a spicy, pungent and pleasant flavor (Jayashree *et al*. 2012) [8]. Owing to the presence of polyphenols, terpenoids, isoterpenoid compounds i.e. gingerol and its derivatives, ginger is effective against several pharmacological actions such as common cold, high cholesterol, ulcers, atherosclerosis, sore throat, indigestion, diabetes, cardiovascular diseases and thus, finds its use all over the world as a spice, condiment, ginger paste, dried powder etc. (Badreldin *et al.* 2008; Radhika *et al.* 2017) [3, 16]. However, due to its pungent aroma and sharp, spicy flavour, there are limited opportunities to develop processed food products from ginger (Nath *et al.* 2013) [13]. Therefore, the key to successful promotion of any ginger based product will be to find the appropriate pre-treatments and processing conditions to maximize sensorial acceptability for ginger based products. Candy preparation is an osmotic dehydration (OD) process which aims at reducing the moisture content and increasing the sugar content of the food sample with a lower water activity and longer shelf-life of the final product. Blanching, an important pre-treatment for ginger candy preparation which not only enhances the osmotic process apart from deactivation of enzymes, but also leads to the leaching out of phytochemicals, thus, subsequently, decreases the antioxidant potential. Anthocyanins, the largest subclass of flavonoids, is a powerful group of antioxidants which prevent important cells in our body from being oxidized by not only removing the products of oxidation called free radicals, but also by offering themselves up for oxidation and therefore protect the body from diseases and premature aging.

Plum fruits are an excellent source of antioxidants, calcium, magnesium, iron, potassium and fibre besides substantial amount of vitamin C (Sabarez *et al*. 1997) [17] and abundant anthocyanins. Further, in the conventional method of ginger candy preparation, honey may be an effective replacement for sugar which is generally used as a sweetener. The high concentration of fructose and glucose results in increased rate of mass transfer as being low molecular sugar compounds. Honey also serves as a source of natural antioxidants as it prevents deteriorative oxidation reactions and inhibit browning in fruits and vegetables (Oszmianski and Lee, 1990; McLellan *et al*. 1995; Chen *et al*. 2000) [15, 12, 5]. Therefore, in the present study, an attempt has been made to utilize the phytochemical rich extract of plum pulp as a source of anthocyanins and honey as a sweetner for the development of ginger candy.

Materials and Methods

Preparation of rich ginger candy

Fresh ginger rhizomes were collected from local market of Solan and washed thoroughly followed by air drying at room temperature (25 ± 2 °C) for 1–2 h, mechanical peeled and sliced to varying (5.0-25.0 mm) thickness (Kaushal *et al*. 2014) [10]. Ginger slices were blanched in boiling water containing 1.0 per cent lime juice for 15 minutes and mechanically dried to optimize the thickness of ginger slices on the basis of drying and sensory characteristics. The ginger slices of optimized thickness is steeped in 70°Brix sugar syrup (1:3) for variable process time (1 to 8 hours) to select the best time temperature combination. A process protocol was then standardized by using a combination of plum pulp with sweetening agent either cane sugar or honey to form a anthocyanin hypertonic solution of 70 ºB for dipping of ginger slices for varying time period and comparing with pure sugar syrup or honey as immersion solutions. The steeped mass was drained after attaining the equilibrium between slices and solution and dried at 50 °C, cooled and packed in laminated aluminium pouches for analysis.

Analytical methods: Total soluble solids (TSS) and titratable acidity of the fresh and processed products were analysed as per the standard methods (AOAC, 2004) [2]. Antioxidant activity (DPPH free radical scavenging activity) of fresh ginger rhizome and candy was measured as per the standard method of Brand-Williams *et al*. (1995) [4] while, the total phenols were determined by using Folin-Ciocalteu reagent using gallic acid as standard (Sadasivam and Manickam, 1991) [18]. Total proteins of candy were determined by Lowry’s method as described by Sadasivam and Manickam (1991) [18]. The data on chemical characteristics of fresh and processed ginger were analyzed statistically by following Completely Randomized Design (CRD) detailed by Cochran and Cox (1967) [6], while, data pertaining to sensory evaluation were analyzed according to Randomized Block Design (RBD) as described by Mahony (1985) [11]. Triplicate determinations were made for each attributes.

Results and discussion

Physico-chemical characteristics of fresh ginger rhizome var. Himgiri revealed the presence of high moisture content (82.39 ± 0.05%) and low titratable acidity (0.15 ± 0.02 %) which emphasized the need of proper postharvest management. The amount of ascorbic acid (8.48 ± 0.53 mg/100 g), total phenols (10.18 ± 0.03 mg/100 g), antioxidant activity (57.45 ± 0.60 %) protein (2.73 ± 0.06%) crude fibre (1.41 ± 0.02 %) and total ash (1.66 ± 0.02 %) highlighted the nutritional significance of ginger and was found to be in conformity with the result reported by Kaushal *et al*. (2017) [10]; Sultan *et al*. (2005) [21]; Shahid and Hussain (2012) [19].

Among the different blanched ginger slices, maximum drying time of 10.01 hours was taken by 25.00 mm thick slices to reach to a moisture content of 16.69 per cent (Table 1.0) while it took only 4.02 hours to dry the ginger slices having 5.00 mm thickness to reach to a moisture content of 11.51 per cent thus clearly showing that with increased thickness the time taken for drying to specific moisture content increased which was in agreement with the results of Nath *et al.* (2013) [13] and Aktar *et al*. (2009) [1].

Table 1: Effect of drying time on reduction in moisture content of ginger slices with varying thickness

Thickness (mm) / Drying time (hrs)	5.00	10.00	15.00	20.00	25.00
	Moisture content				
0	84.22	84.22	84.22	84.22	84.22
1	65.63	80.91	77.72	77.89	79.90
2	38.69	58.20	59.86	63.45	72.97
3	23.58	42.01	42.24	54.21	64.68
4	11.51	30.55	31.83	39.42	53.17
5	11.50	14.98	20.27	34.23	48.02
6		14.95	16.35	31.60	36.16
7			16.30	25.23	31.45
8				16.37	29.04
9				16.35	23.58
10					16.69
11					16.60

The ginger slices of thickness 10.0, 15.0 and 20.0 mm showed drying time of 5.00, 6.00 and 8.01 hours respectively.

Further, the data pertaining to sensory characteristics of dried ginger slices with varied thickness shows significantly higher scores (7.70) of texture for slice thickness 10.00 mm followed by slice thickness 5.00 mm and minimum score (5.50) for slice thickness 25.00 mm. The taste and colour scores of ginger slices of varying thickness (5.00-25.00 mm) were found to be non-significantly different among the treatments. On the basis of overall acceptability, slice thickness of 10.00 mm received maximum score of 7.80 followed by slice thickness of 5.00 mm with a score of 7.50 (Fig 1) while, minimum score (6.00) was received by slice thickness 25.00 mm followed by ginger slices of 20.00 mm thickness.

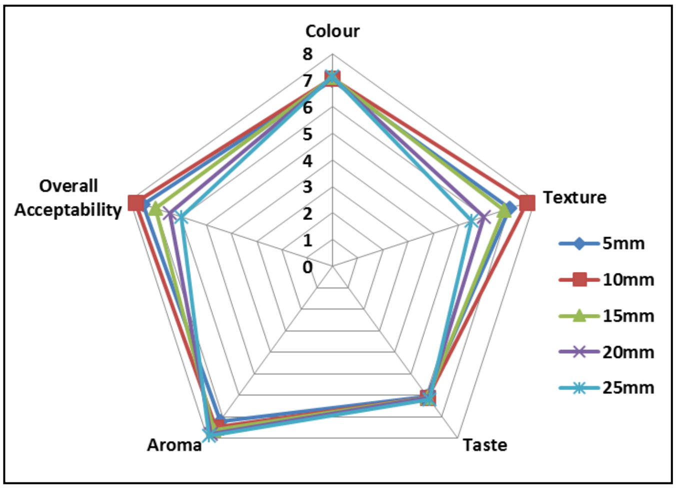

Fig 1: Sensory scores for dehydrated ginger slices of varying thickness

Thus, on the basis of sensory scores and drying characteristics the ginger slices of thickness of 10.00 mm and 5.00 mm were selected and was compared with 7.50 mm thick slices.

Similar to previous findings, the results pertaining to the sensory evaluation for optimization of thickness for osmotic dehydration revealed non significant differences in the colour characteristics of ginger slices of varying thickness (5.00, 7.50 and 10.00mm). Data appended to texture characteristics showed significantly higher scores (8.00) for slice thickness 7.50 mm followed by 7.70 and 7.00 scores for slice thickness 10.00 and 5.00mm respectively. Further, the taste characteristics of ginger slices was found to be non significantly different among the treatments. Maximum score for aroma was obtained by treatment slice thickness10.00 mm followed by treatment slice thickness 7.50 mm and slice thickness 5.00 mm with a score of 7.50, 7.40 and 7.20 respectively.

The data in Fig 2.0 regarding the drying behavior of slices the ginger slice of thickness 7.50 mm showed a drying time of 4.30 hours to reach to a moisture content of 14.09 per cent as against 6 hours for 10 mm thick slices to dry to similar moisture content.

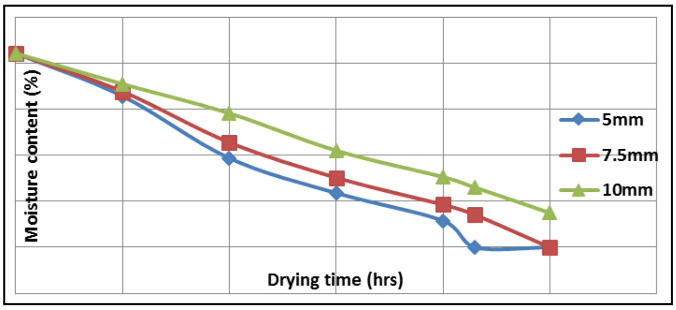

Fig 2: Dehydration curve for ginger slices

Thus, on the basis of sensory scores and drying behavior, the ginger slices thickness of 7.50 mm was optimized for conducting the osmotic studies.

Standardization of optimum time-temperature combination for osmotic dehydration of ginger slices

The results pertaining to optimization of time-temperature combination for osmotic dehydration of ginger slices showed that the weight of slices was reduced in all the treatments with respect to steeping time (1-10 hours) following osmotic dehydration, as weight reduction, solid gain and water loss are affected by process time (Fito *et al.* 2001) [7].

The data pertaining to osmotic parameters (Fig 3.0) highlighted that after 1.0 hour of steeping in osmotic solution of 70 ºB, the ginger slices showed a weight reduction of 9.96 per cent with a corresponding solid gain and moisture loss of 5.92 per cent and 68.51 per cent respectively.

The total soluble solid of ginger slices after 1.0 hour of steeping was recorded as 10.15ºB with a parallel total soluble solid of syrup as 68.85 ºB. Similarly, at 3.0, 4.0 and 5.0 hours of steeping time in the osmotic solution of 70 ºB the ginger slices showed a weight reduction of 19.96, 23.08 and 24.20 per cent with a corresponding solid gain and moisture loss of 8.43, 10.60 and 13.00 per cent and 57.90, 55.86 and 52.89 per cent respectively.

While after 6.00, 7.00 and 8.00 hours of immersion time a weight reduction of 27.00, 29.60 and 30.00 per cent and a solid gain of 16.60, 16.80 and 17.20 per cent was recorded respectively with a corresponding water loss of 43.60, 44.40 and 47.20 per cent.

The equilibrium of total soluble solids between slices and syrup was evident at 8 hours of steeping with a value of (Fig. 4.0) 32.03 ºB for slices and 35.10 ºB for syrup.

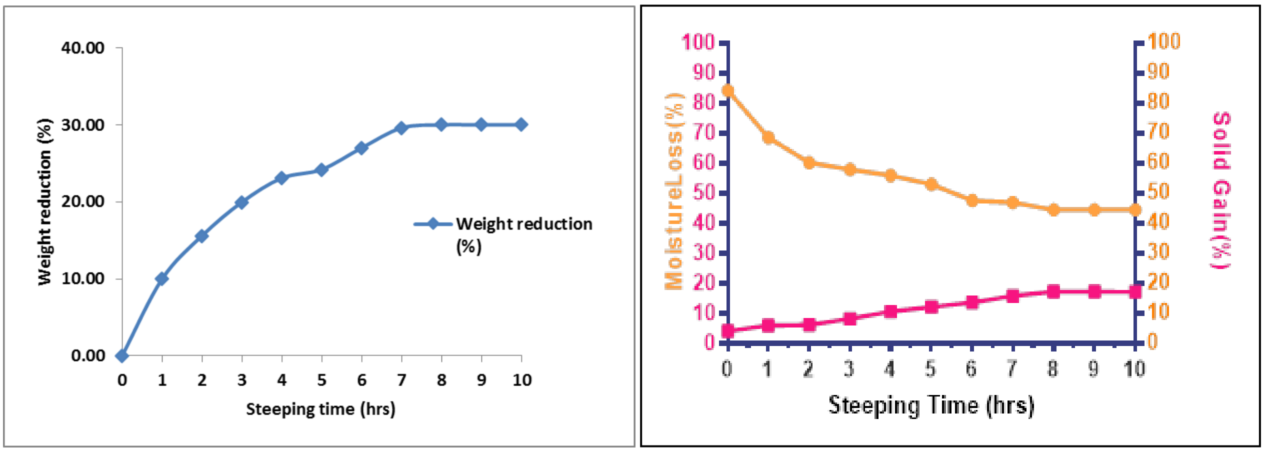

Fig 3: Effect of immersion time on per cent weight reduction, water and solid gain of ginger slice

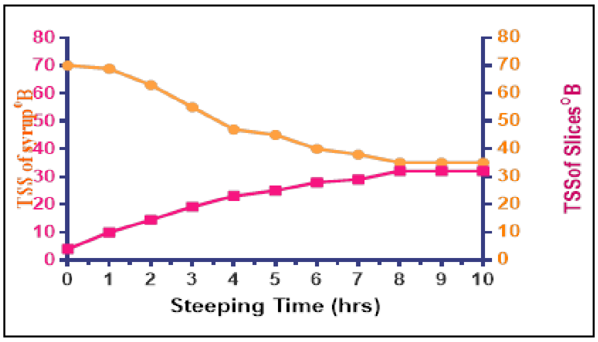

Fig 4: Effect of immersion time on TSS of immersion solution and slices of ginger

Sugar uptake results in the development of a concentrated solid layer under the surface of the slices, decreasing the osmotic pressure gradient across the ginger slices interface and thereby decreasing the driving force of water flow.

Thus, the steeping time of 8.00 hours (T_8) was optimized on the basis of equilibrium of total soluble solids attained between slices and syrup and was therefore selected for further studies.

Thus a steeping time of 8.0 hours in 70 ºB sugar solution maintained at 50 ºC was standardized for ginger slices having a thickness of 7.50 mm.

Standardization of protocol for the development of anthocyanin enriched ginger candy

Perusal of data in Table 2.0 shows that the ginger slices dipped in sugar syrup (T_1) attained equilibrium in 8 hours with TSS of slices as 32.03 ºB and syrup as 35.10 ºB while in honey solution (T_3) the equilibrium was attained in 7 hours with TSS of slices as 32.06 ºB and syrup as 35.24 ºB. While both in treatment T_2 and T_4 containing plum pulp the equilibrium between slices and syrup was attained in 5 hours with TSS of slices as 32.40 and 34.02 ºB in T_2 and T_4 and TSS of syrup as 35.60 and 35.02 ºB respectively. Thus an immersion time of 5 hours was standardized for the preparations of anthocyanin enriched ginger candy. The data of osmotically drained ginger slices (Table 3.0) showed that maximum weight reduction was observed in hypertonic solution of the plum pulp and honey (T_4) as 31.50±2.93 per cent followed by pure honey (T_3) as 28.45±3.01 per cent, plum pulp and sugar (T_2) 26.20±2.95 per cent and sugar syrup (T_1) as 24.20±3.02 per cent. Further, a hypertonic solution of plum pulp and honey (T_4) evidenced a maximum water loss (56.50±2.70 %) followed by pure honey (T_3) as 47.00±2.83 per cent, plum pulp and sugar (T_2) 46.00±2.74 and sugar syrup (T_1) as 37.20±2.85 per cent. Similarly, a hypertonic solution of plum pulp and honey (T_4) appended a maximum solid gain of 25.00±0.53 per cent followed by pure honey (T_3) 18.50±0.39 per cent, plum pulp and sugar (T_2) 20.03±0.45 per cent and sugar syrup (T_1) as 13.07±0.34 per cent.

Table 2: Effect of immersion solution and steeping time on TSS of slices and drained syrup

Treatment / Steeping Time (hours)	T_1 Sugar syrup		T_2 Plum pulp+ Sugar		T_3 Honey		T_4 Plum pulp+ honey	
	TSS of slices (ºB)	TSS of syrup (ºB)	TSS of slices (ºB)	TSS of syrup (ºB)	TSS of slices (ºB)	TSS of syrup (ºB)	TSS of slices (ºB)	TSS of syrup (ºB)
1	10.02	63.85	12.04	59.02	11.04	61.50	12.60	58.50
2	14.50	58.05	16.60	55.04	15.60	56.08	17.20	54.50
3	19.20	51.02	23.05	49.03	20.10	50.03	24.10	48.06
4	23.05	47.01	28.80	42.05	24.50	45.80	30.50	41.01
5	25.02	45.03	32.40	35.60	27.20	42.06	34.02	35.02
6	28.01	40.05	33.01	35.14	30.10	38.96	34.90	35.60
7	29.02	38.02	32.02	36.03	32.06	35.24	35.03	36.02
8	32.03	35.10	32.07	36.13	32.04	35.20	35.08	36.48
9	32.00	35.15	-	-	32.08	35.29	-	-
10	32.05	35.17	-	-	32.06	35.25	-	-
CD 0.05	0.01	0.02	0.01	0.02	0.01	0.02	0.02	0.01

Higher solid gain and water loss were observed in honey treated sample as compared to sucrose-treated sample as honey contains simple sugars like fructose and glucose which are low molecular weight osmotic agents thus have enhanced mass transfer during osmotic dehydration. The higher rate of penetration of low molar mass molecules results in the solid enrichment during the process, resulting in the promotion of water loss.

Table 3: Effect of osmotic solution on osmotic dehydration behaviour of ginger slices

Treatments / Parameter	T_1 Sugar syrup	T_2 Plum pulp + Sugar	T_3 Honey	T_4 Plum pulp + Honey
Weight Reduction (%)	24.20±3.02	26.20±2.95	28.45±3.01	31.50±2.93
Water Loss (%)	37.20±2.85	46.00±2.74	47.00±2.83	56.50±2.70
Solid Gain (%)	13.07±0.34	20.03±0.45	18.50±0.39	25.00±0.53

Nutritionally, the ginger slices immersed in hypertonic solution containing plum pulp contained appreciable amount of anthocyanin content(16.33±0.53to 18.64±0.63 mg/100g) in treatment T_2 and T_4, antioxidant activity (50.45±0.53 to 52.35±0.60%), total phenols (9.84±0.25 to 13.08±0.28 mg/100g) and ascorbic acid (6.11±0.45 to 6.98±0.49 mg/100g) as against sugar or honey solutions with antioxidant activity, total phenols and ascorbic acid in the range of 42.75±0.51 to 44.25±0.55 per cent, 7.56±0.13 to 11.54±0.12 mg/100g and 3.92±0.35 to 5.32±0.39 mg/100g respectively (Table 4.0).

Table 4: Effect of osmotic solution on quality characteristics of ginger slices

Treatments / Parameter	T_1 Sugar syrup	T_2 Plum pulp + Sugar	T_3 Honey	T_4 Plum pulp + Honey
Anthocyanin content (mg /100g)	-	16.33±0.53	-	18.64±0.63
Antioxidant activity (%)	22.75±0.51	50.45±0.53	28.25±0.55	52.35±0.60
Total phenol (mg/100g)	7.56±0.13	9.84±0.25	11.54±0.12	13.08±0.28
Ascorbic acid (mg/100g)	3.92±0.35	6.11±0.45	5.32±0.39	6.98±0.49

The above experiment concludes that a dipping time of 5 hours at 50 ºC temperature was found optimum for the preparation of anthocyanin enriched ginger candy in an immersion solution of plum pulp whose TSS is raised to 70 ºB by either sugar or honey while a dipping time of 7 hours has been standardized for ginger slices in honey solution and 8 hours for slices in sugar syrup solution.

The color parameters of ginger candy measured (Table 5.0) showed that the sugar syrup (control) immersed ginger candy recorded an L * value of 29.15, a* 0.67 and b* 8.14 while treatment plum pulp + sugar had color values as L* 20.14, a* 6.63 and b* 5.19. The treatment T_3 using honey as dipping solution had L* 21.68, a*1.32and b* 6.04 values, as compared in treatment T_4 (plum pulp + honey) where L* 18.36, a*9.37and b* 4.39 values was noticed.

Table 5: Colour value of ginger candy

Treatments	L* (Lightness)	a* (Redness-greeness)	b* (Yellowness blueness)
Sugar syrup (T_1)	29.15	0.67	8.14
Plum pulp+ sugar (T_2)	20.14	6.63	5.19
Honey (T_3)	21.68	1.32	6.04
Plum pulp + honey (T_4)	18.36	9.37	4.39
CD $_{0.05}$0.02		0.019	0.019

Sugar impregnation seemed to maintain lightness resulting in a final product close to that of fresh commodity. The colour parameters L* and a* values correlate well to colour changes in fruit tissues (darkening) due to anthocyanin uptake, L* values decrease with anthocyanin rich solution uptake and a* values increase, the increase in redness and yellowness was clear and seem to be result of solids uptake during osmotic pre-treatment.

Conclusion
The present study concludes that organoleptic characteristics and chemical composition of conventially osmo-dried ginger candy can be improved by substituting the osmotic solution containing sugar syrup with plum pulp and honey or enriching sugar syrup with plum pulp which is a source of anthocyanin. Thus, the development of anthocyanin enriched ginger candy will have functional and nutritional properties of ginger, plum and honey which seems to be a profitable venture for efficient utilization of fresh ginger rhizome and plum fruits thereby enhancing income of growers along with development of a novel therapeutic confectionary product.

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