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Development of apple candy enriched with anthocyanin using high-pressure processing and its storage stability

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Abstract
The present work shows the budding application of high-pressure processing in the development of nutraceutical enriched food commodities and their stability during storage. The storage studies indicated that anthocyanin enriched apple candy filled in LDPE pouches at ambient conditions had significantly ($p \leq 0.05$) increased moisture uptake from (19.76 to 23.17%) as compared to PET/Foil/PE film laminates (19.76 to 20.92 %) by the close of 45 days period. The retention of bioactive content also pointedly ($p \leq 0.05$) decreased with storage period especially for samples stored in LDPE pouches compared to PET/Foil/PE film laminates**.** The results showed that the candy packed in PET/Foil/PE film laminates can be recommended as a apt packing material because of higher retention of the infused anthocyanin content and better textural attributes as related to the candies packed in LDPE pouches.

Keywords: high pressure processing, storage, infusion, candy, mass transfer, packaging material

Introduction

Hastily growing consumer wakefulness for ready-to-eat products, chiefly when they are associated with high nutraceutical value due to shifting lifestyles and eating practices are increasing (Henry, 2010) [13]. Because of their growing acceptance by health-conscious customers and the willingness of advertisers to make awareness of current products, functional foods are an evolving area in food science. A functional food is termed as a natural or processed food comprising noted, quantifiable and quantitative biologically active compounds, that provide clinically proven and well-known health benefits, and is therefore a key source of chronic disease prevention, management and cure (Hasler, 1998) [11].

It is not an easy task to integrate the active component into the solid food system. Several scientists have shown the use of osmotic treatment to impregnate physiologically active composites such as minerals (Barrera *et al*., 2004; Gras *et al*., 2003) [4, 7], phenolic compounds (Rozek *et al*., 2009; Rozek *et al*., 2010a, b) [25, 27], curcuminoids (Bellary *et al*., 2011) [5], probiotics (Alzamora *et al*., 2005) [1], and nutrients (Hironaka *et al*., 2011) [14] in food products. Much of the processes such as osmosis, diffusion and hydrodynamics play a major role in the phenomenon of mass transfer (Rastogi *et al*., 2000; Rastogi *et al*., 2002) [23, 24]. Numeral techniques were explored to advance osmotic mass transfer rates, including vacuum (Rastogi & Raghavarao, 1996; Fito *et al*., 2001) [20, 1], cold isostatic processing (Rastogi *et al*., 2007; George *et al*., 2016) [5, 8] or sonication (Bellary *et al*., 2011; Rastogi, 2011) [21] as well as pulse electrical field, and have been known to increase rates of mass transfer during osmotic treatments.

Many studies are available to improve the inherently low level of mass transfer processes for the impregnation of physiologically active compounds into solid food matrices such as $CaCl_2$ infusion into carrots (Sila *et al*., 2004), PME in strawberries (Duvetter *et al*., 2005), ascorbic acid in pineapple (Perera *et al*., 2010), anthocyanin in apple slices (George *et al*., 2016) [8], quercetin into frozen-thawed cranberries (Mahadevan *et al*., 2014) [15] Similarly, Tola and Ramaswamy (2013) studied HPP acidification of low acid foods like carrot. HPP acidification provided more uniform and rapid acidification compared to conventional methods.

As communal distress about artificial food colors has augmented presently, customers and food producers aspire dyes from natural resources. Potential alternative to the widely used unreal food colors, anthocyanins are attracting the food trade and customers (He & Giusti, 2010) [12] It create the principal and perhaps the utmost significant set of water-soluble natural pigments (Takeoka & Dao, 2002) [30]. *Garcinia indica Choisy* (popularly known as kokum) is an affluent resource of anthocyanins. It is considered as a budding substitute for artificial colors because of their intense striking shade and aqueous solubility that allows their integration into liquid food systems apart from their numerous health benefits (Nayak *et al*., 2006; Nayak *et al*., 2009) [17, 18].

According to a new survey, the majority of customers indicated their inclination for a variety cultivar of apple over another because of probable taste and mouth-feel (Doyle, 2004). This is usually accredited to their better-quality. Fuji apple (*Malus domestica* B.), a hybrid between Red Delicious and Ralls Janet, is a cultivar that stands out for its outstanding sensory characteristics such as juicy, firm, crispy, soft, spicy taste, high in sugar and weak in acidity, as well as good storage capacity (Stebbins *et al*., 1991; Yoshida *et al*., 1995). The aim of the current work was to infuse kokum anthocyanin into apple slices by osmotic dehydration using pretreatment with high pressure processing to develop a osmo dehydrated product and study the shelf-life of apple candies impregnated with anthocyanin.

2. Materials and methods

2.1 Preparation of raw materials

The raw materials were bought from a local market and processed at low temperature until further use. The anthocyanin was extracted in aqueous solution under ambient conditions Nayak *et al*. (2010). This syrup has been used as an anthocyanin source. The kokum extract was blended in a ratio of 1:2.5 with jamun juice to mask the kokum juice's sourness. The apples were washed, wiped, peeled, cored and cut in rounded shapes (7 mm diameter and 3.5 mm thickness) uniformly. (AOAC, 1998, Procedure number 934.06).

2.2. High pressure processing

In a cylindrical pressure vessel (Model 7690, Khoday Hydraulics Ltd., Mumbai), the apple slices (7 mm diameter and 3.5 mm thickness) were subjected to high pressure. The system had a 1L working capacity and suggested up to 400 MPa operating pressure. The samples were suspended in pouches of low density polyethylene (LDPE) containing impregnating solution in the ratio 1:3. The pouches are heat sealed after the removal of air and then the specimens were subjected to a pressure of 250 MPa for 10 minutes. The conditions were selected based on our earlier work (George *et al*., 2016) [8], that found that high-pressure (250 MPa) treatment facilitated to infuse the highest amount of anthocyanin.

3.1.11.3 Candy making

Later, in the individual containers comprising sugar solutions of varying concentration (30, 40, 50, 60 and 70°Brix encompassing anthocyanin extract), samples were pre-weighed and exposed to candy making. The proportion of the sample volume to that of osmotic solution was kept at 1:3 during impregnation and candy making to check that the concentration of the surrounding solution did not differ provocatively during the experiment.

2.3 Air drying

Anthocyanin infused samples were air-dried at 40ºC until a water activity of 0.28 in a cabinet drier CPW550 TOP (Pol-Eko- Aparatura SP.J., UK) with crosswise air flow, air velocity 1.8 m/s.

3.1.12 Storage studies

3.1.12.1 Packaging of sample

Around 50 g of sample was filled in two dissimilar sorts of packages (i) Laminated pouches viz., PET/Foil/PE pouches (Schlimme and Rooney, 1994). The packaging material requirements chosen were in accord with BIS, 1982. The selection of PET / Foil / PE and LDPE is based on their low transmission rate for moisture and oxygen, which, in addition to being attractive, would be appropriate for extending the shelf life. The samples were packaged in a 50 g package pack and processed under ambient conditions (25 ± 1 ° C with 63 ± 2% RH). During a period of one week, the samples were evaluated for physiochemical and microbiological qualities along with sensory attributes.

3.1.12.2 Moisture determination

Conferring to procedure no. 934.06 AOAC (1998).

3.1.12.3 Anthocyanin estimation

All samples were analyzed by pH-differential spectrometric method (Wrolstad *et al*. 2005).

3.1.12.4 Rate of anthocyanin degradation

The degradation of anthocyanin followed the first order reaction kinetics. The order of kinetics for retention of color during storage was obtained by employing the method (Cemeroglu *et al*., 1994; Garzon & Wrolstad, 2002).

3.1.12.5 Color determination

The L*, a* and b* values of control (untreated) and high pressure treated samples were measured using Minolta Chroma Meter, CM6500D (Minolta Corp., Osaka, Japan).

2.8 Texture profile analysis

It was did at room temperature (~25ºC) using a texture analyser (LLOYD-LR-5 K Surrey, UK) with a load cell of 500 kg. The circular specimen (7 mm diameter and 3.5 mm thickness) was flattened (75 percent compression) on a non-lubricated surface using a flat disk probe (38 mm in diameter) with a steady 2 mm / s crosshead rate. The peak force needed to compress the samples was called a hardness measure (Bourne, 1978). Based on the definition as described, TPA determined cohesiveness, springiness, and chewiness (Bourne, 1978). For each procedure, three calculations are made.

2.9 Microbiological analysis

For analysis, 5.0 g of polyphenol infused slices were taken, ground in decontaminated pestle and mortar to prepare the inoculum in 15 mL of brine. To detect the growth of yeast, mould and total aerobic bacteria during the storage period the resulting suspension was serially diluted and plated in duplicates on potato dextrose agar (PDA) (Difco) and plate count agar (PCA) (Difco).

2.10 Sensory analysis

The analysis was based on quantitative descriptive analysis (QDA) (Stone and Sidel, 1998) [29]. Trained panelists evaluated sensual qualities such as colour, texture, aroma, and overall product-specific quality. The mean scores were determined for the human characters and the profile was drawn.

2.11 Statistical analysis

At $p \leq 0.05$ using MS-Excel the data were analyzed using analysis of variance (ANOVA) and Tukey-Kramer test. All the experiments were performed in triplicates and average values were reported.

3. Results and discussion

3.1 The effect of the surrounding solution on the mass transfer of solid moisture and anthocyanin content during candy production

The candies were developed using apple slices (7 mm diameter and 3.5 mm thickness). The difference in moisture, solids and anthocyanin contents during candy making process is stated in (Fig.1). The high pressure treated slices (250 MPa/10 min) were subjected to osmotic treatment in anthocyanin extract for 5.0 h. There was significant ($p \leq 0.05$) change in the moisture, solid and anthocyanin contents of the apple slices during osmotic dehydration. The application of HPP was noted to further boost the mass transfer of moisture, solid and anthocyanin content in apple slices (Fig. 1a-c). Due to higher osmotic pressure inside the apple slices compared to the surrounding solution the slices submerged in anthocyanin extract as surrounding medium resulted in the absorption of water into slices (Fig.1a). At the same moment, apple solids were also diffused into the underlying liquid (Fig. 1b). The transfer of water into slices was also accompanied by anthocyanin impregnation, because the impregnate was water dispersible. Rozek *et al*. (2010) [5] demonstrated that the infusion of total grape phenolic compounds in the model food system was higher when subjected to a surrounding solution of grape extract containing phenolic compounds in pure water compared to 50% sucrose in grape extract as osmotic solution. Anthocyanin infused slices were further processed in anthocyanin extract containing sucrose as an osmotic solution ranging from 30 to 70 ° Brix in each solution for a 24-hour period. Increase in the concentration of the surrounding solution significantly ($p \leq 0.05$) reduced moisture and increased the solid content of the anthocyanin impregnated slices (Fig. 1a-c). Increased concentration of Osmotic solutions resulted in a decrease in the driving force for mass transfer compared to the situation when anthocyanin extract was used as an surrounding solution.

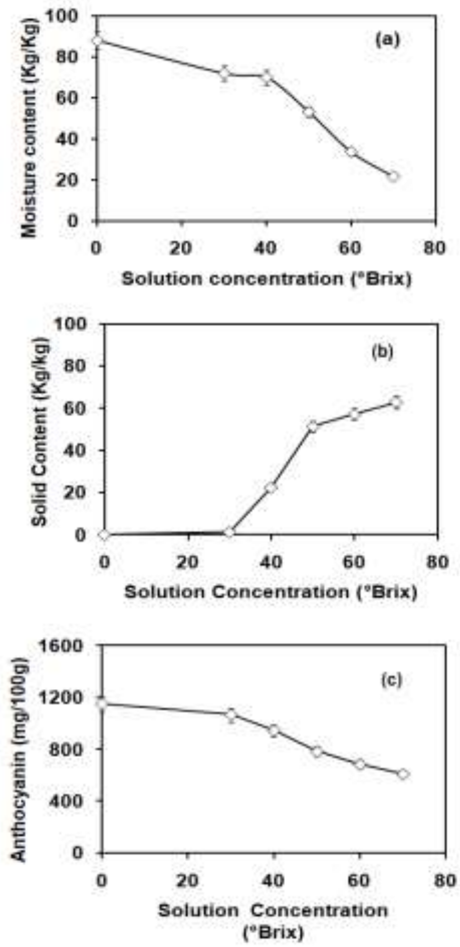

Fig 1: Change in moisture content (a) solid content (b) and anthocyanin content (c) during candy making process

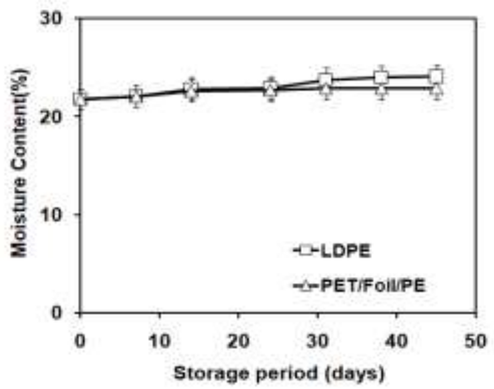

Fig 2: Change in moisture content of candy during storage in different packaging material (LDPE and PET/Foil/PE).

4.1.2.2 Changes in quality attributes of anthocyanin impregnated apple candy during storage

In addition, the product developed was packaged in low-density polyethylene (LDPE) and laminated pouches (PET / Foil / PE) which were stored for a period of 45 days under ambient storage conditions (27±1 ° C with 65±2% RH). During this time, changes have been observed in the product's quality parameters to assess the product's shelf life.

4.1.2.3 Moisture content

There was a gradual increase in the product's moisture content in both the packaging materials used to pack the products, with the increase in the storage period. However, depending on the packaging material used for storage, the percentage of moisture gain ($p \leq 0.05$) varied significantly. From (Fig.2) apple slices packed in LDPE were shown to have a significantly higher moisture pickup ($p \leq 0.05$) (19.76 to 24.07%) compared to PET / Foil / PE (19.76 to 22.90%) By the end of the 45-days period. Durrani *et al*. (2011) also reported a 28 percent moisture content in fresh carrot candy, which gradually increased to 33.0 percent at the end of the storage period in the LDPE pouches. However, LDPE oxygen transmission rate was reported to be 7800 cm^3 m^{-2} per day and 18 g / $m^{-2/}$d water vapor transmission (WVTR) at 37.8 ° C and 90% RH (Schlimme and Rooney, 1994), whereas PET / Foil / PE oxygen transmission rate (OTR) was 2 cm^3 m^{-2} per day and 0.7 g / m^{-2}/d water vapor transmission at 37.8 °C and 90% RH (Vijayalakshmi *et al*., 2003). This change in LDPE's OTR and WVTR may have contributed to increased pick-up of moisture during storage.

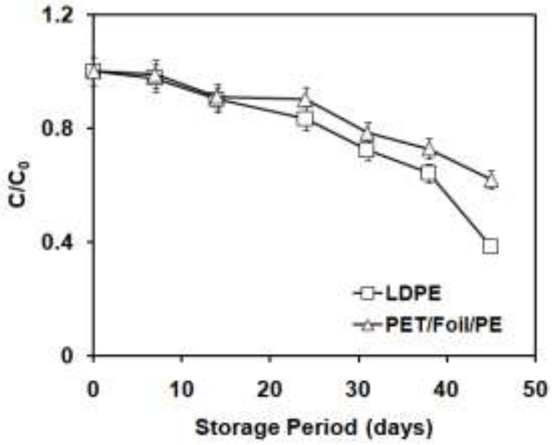

Fig 3: Kinetics of anthocyanin degradation of candies during storage in different packaging material (LDPE and PET/Foil/PE)

4.1.2.4 Kinetics of anthocyanin degradation

As a photo-sensitive pigment, anthocyanin gets reduced to compounds such as quercetin, phloroglucinaldehyde and protocatechuic acid when exposed to heat or light (Sadilova *et al*., 2007). There was, however, a significant difference in anthocyanin retention between the two packaging materials used (Fig.3). Linear regression verified that the first order reaction was accompanied by the degradation of anthocyanin in apple slices. Several authors also reported a first-order reaction to anthocyanin degradation in 45 and 71°Brix sour cherry concentrate (Cemeroglu *et al*., 1994), violet and red flesh potato extracts (Reyes & Cisneros-Zevallos, 2007) and black currant nectar during storage.

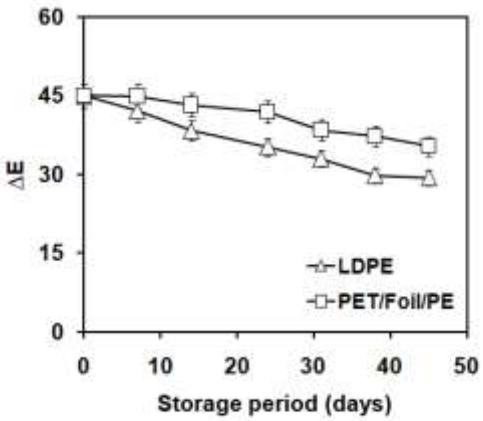

Fig 4: Change in total color difference of anthocyanin infused apple candy during storage.

4.1.2.5 Total color difference of anthocyanin infused apple candy

During storage, the total color difference (TCD) in apple slices were shown in (Fig.4). TCD (Fig. 4), an essential attribute of any colored material, has been found to decrease ($p \leq 0.05$) with storage in samples packed in LDPE pouches. However, it is evident from (Fig.4) that anthocyanin retention ($p \leq 0.05$) decreased significantly with storage period compared to PET / Foil / PE, especially for samples stored in LDPE pouches. Patras *et al.* (2011) [19] also reported a similar trend in anthocyanin degradation in strawberry jam storage.

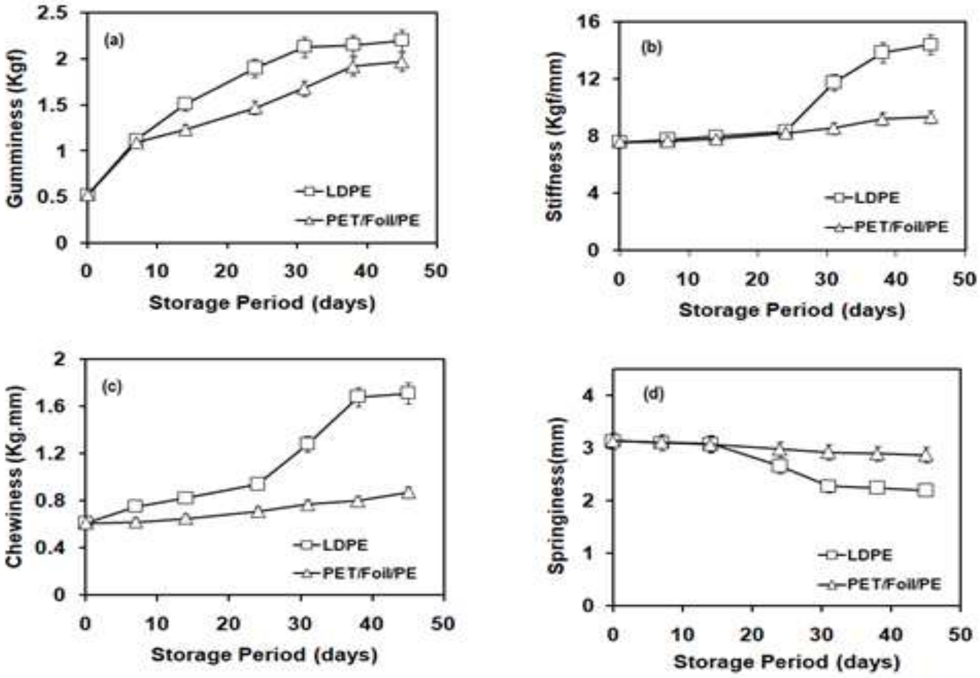

Fig 5: Textural parameters (a) gumminess (b) stiffness (c) chewiness and (d) springiness of anthocyanin enriched apple candy during storage

4.1.2.6 Textural and sensory attributes

Quality plays a major role in the approval of a product by the customer.

During the storage period, it was found that the gumminess, stiffness and chewiness of fruit candy packed in LDPE pouches increased.

Whereas springiness in candy stored in LDPE pouches was found to decrease (Fig. 5). It is therefore obvious that the product packaged in two packaging materials had a significant effect on the candy's textural parameters ($p \leq 0.05$). The sensory attributes of the samples stored in either PET / Foil / PE or LDPE pouches did not change much during storage (Fig. 6). Apple slices had attractive pink colour, circular in shape and embedded with sugar crystals (Fig. 7). Firmness was of optimum level (6.5). Sample had fruity and more of acidic aroma (6.1). Sweetness was of 8.5 intensity and sourness 6.2. Overall quality score was on the acceptance level (9.5).

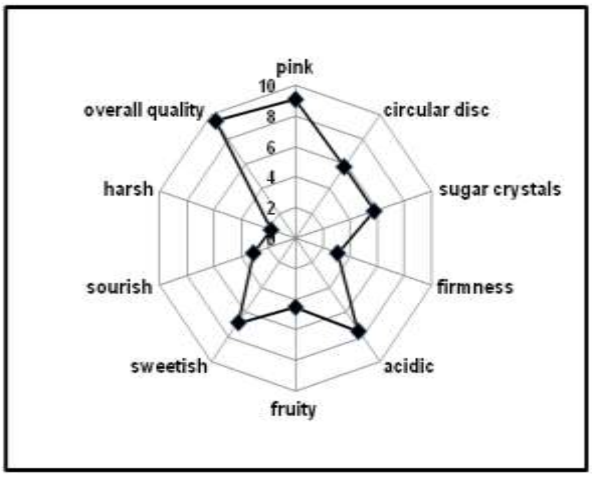

Fig 6: Sensory profile of anthocyanin enriched apple candy

Fig 7: Anthocyanin enriched apple candy

4.1.2.7 Microbiological stability

The product developed packaged in LDPE and PET / Foil / PE was microbiologically stable under ambient storage conditions with no bacterial or fungal contamination up to 45 days.

4. Conclusion

High pressure processing has been shown to be a practicable approach for infusing bioactive compounds in foods without altering their normal matrix substantially. Apples treated with HPP stated a significant increase in the infused anthocyanin content over those handled under ambient conditions. Mass transfer rates under HPP had also been improved and processing period was reduced. The present work had shown the potential application of HPP to develop food products infused with nutraceuticals. The results indicated that the candy packed in PET / Foil / PE pouches could be recommended as an appropriate packaging material due to higher retention of the content of the infused anthocyanin and better textural attributes compared to packed in LDPE pouches.

5. Acknowledgements

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6. References

1. Alzamora SM, Salvatori D, Tapia MS, López-Malo A, Welti-Chanes J, Fito P. *et al*. Novel functional foods from vegetable matrices impregnated with biologically active compounds. Journal of Food Engineering, 2005; 67:205-214.
2. Amami E, Vorobiev E, Kechaou N. Modelling of mass transfer during osmotic dehydration of apple tissue pre-treated by pulsed electric field. LWT- Food Science and Technology, 2006; 39:1014-1021.
3. Anderson O, Jordheim M. Anthocyanins: food applications. In proceedings of 5th international congress pigments in food: for quality and health. Finland: Univ. Helsinki Helsinki, 2008, 14-17.
4. Barrera C, Betoret N, Fito P. Ca^{+2} and Fe^{+2} influences on the osmotic dehydration kinetics of apple slice (var Granny Smith), Journal of Food Engineering, 2004; 65:9-14.
5. Bellary AN, Sowbhagya HB, Rastogi NK. Osmoticdehydration assisted impregnation of curcuminoids in coconutslices. Journal of Food Engineering, 2011; 105:453-459.
6. Farr D. High-pressure technology in food industry. Trends in Food Science and Technology, 1990; 1:14-16.
7. Fito P, Chiralt N, Betoret N, Gras ML, Chafer M, Martinez-Monzo J. *et al*. Vacuum impregnation and osmotic dehydration in matrix engineering application in functional fresh food development. Journal of Food Engineering, 2001; 49:175-183.
8. George JM, Selvan TS, Rastogi NK. High-pressure-assisted infusion of bioactive compounds in apple slices. Innovative Food Science and Emerging Technologies, 2016, 33:100-107.
9. Gras Ml, Vidal D, Betoret N, Chiralt A, Fito P. Calcium fortification of vegetables by vacuum impregnation. Interactions with cellular matrix, Journal of Food Engineering, 2003; 56:279-284.
10. Gulcin M, Oktay OI, Kufrevioglu A Aslan. Determination of antioxidant activity of lichen Cetraria islandica (L). Journal of Ethnopharmacology, 2002; 7:325-329.
11. Hasler CM. Functional foods: their role in disease prevention and health promotion. Food Technology, 1998; 52:57-62.
12. He J, Giusti MM. Anthocyanins: natural colorants with health-promoting properties. Annual Review of Food Science and Technology, 2010; 1:163-187.
13. Henry CJ. Functional foods. Eur J Clin Nutr, 2010, 64:657-659.
14. Hironaka K, Kikuchi M, Koaze H, Sato T, Kojima M, Yamamoto K. *et al*. Ascorbic acid enrichment of whole potato tuber by vacuum-impregnation. Food Chemistry, 2011; 127:1114-1118.
15. Mahadevan S, Salvi D, Karwe MV. High pressure-enhanced infusion in fresh and Frozen-thawed cranberries: a comparative study. Journal of Food Process Engineering. In press, 2015.
16. Mayor L, Moreira R, Chenlo F, Sereno AM. Effective diffusion coefficients during osmotic dehydration of pumpkin with ternary solutions of NaCl and sucrose. 15th International Drying Symposium (IDS 2006) Budapest, Hungary, 2006, 892-900.
17. Nayak CA, Chethana S, Rastogi NK, Raghavarao KSMS. Enhanced mass transfer during solid–liquid extraction of gamma-irradiated red beetroot. Radiation Physics and Chemistry. 2006; 75(1):173-178.
18. Nayak CA, Rastogi NK, Raghavarao KSMS. Bioactive constituents present in Garcinia indica Choisy and its potential food applications. International Journal of Food Properties, 2009; 13:441-453.
19. Patras A, Brunton NP, Tiwari BK, Butler F. Stability and degradation kinetics of bioactive compounds and colour in strawberry jam during storage. Food and Bioprocess Technology. 2011; 4(7):1245-1252.
20. Rastogi NK, Raghavarao KSMS. Kinetics of osmotic dehydration under vacuum. LWT- Food Science and Technology, 1996; 29:669-672.
21. Rastogi NK. Opportunities and challenges in

application of ultrasound in food processing. Critical Review of Food science and Nutrition, 2011; 51:705-722.

22. Rastogi NK, Niranjan K. Enhanced mass transfer during osmotic dehydration of high pressure treated pineapple. Journal of Food Engineering, 1998; 63:508-511.
23. Rastogi NK, Angersbach A, Knorr D. Evaluation of mass transfer mechanisms during osmotic treatment of plant materials. Journal of Food Science, 2000; 65:1016-1021.
24. Rastogi NK, Raghavarao KSMS, Niranjan K, Knorr D. Recent Developments in osmotic dehydration: Methods to enhance mass transfer. Trends in Food Science and Technology, 2002; 13:48-59.
25. Rozek A, Achaerandio I, Guell C, Lopez F, Ferrando M. Grape phenolic impregnation by osmotic treatment: influence of osmotic agent on mass transfer and product characteristics. Journal of Food Engineering, 2009; 94:59-68.
26. Rozek A, Archaerandio L, Guell C, Lopez F, Ferrando M. Use of commercial grape phenol extract to supplement solid foodstuff. LWT- Food Science and Technology, 2010a; 43:623-631.
27. Rozek A, Garcia-Perez VJ, Lopez F, Guell C, Ferrando M. Infusion of grape phenolics into fruits and vegetables by osmotic treatment: Phenolic stability during air drying. Journal of Food Engineering, 2010b; 99:142-150.
28. Sopanangkul A, Ledward DA, Niranjan K. Mass transfer during sucrose infusion into potatoes under high pressure, Journal of Food Science, 2002; 67:2217-2220.
29. Stone H, Sidel JL. Quantitative descriptive analysis: developments, applications & the future. Food technology (USA), 1998.
30. Takeoka G, Dao L. Anthocyanins. Methods of Analysis for Functional Foods and Nutraceuticals, WJ Hurst (pp. 219–241). Boca Raton, FL: CRC, 2002.
31. Villacis MF, Rastogi NK, Balasubramaniam VM. Effect of high pressure on moisture and NaCl diffusion into turkey breast. LWT- Food Science and Technology, 2008; 41:836-844.