Starch digestibility and glycemic index of *Paranthas* supplemented with *Citrus maxima* (Burm.) Merr. fruit segments

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Abstract The present investigation was undertaken to develop *paranthas* suiting diabetic population with added health benefits. *Paranthas* were prepared using fresh and dry segments of pomelo. The increase in the concentration of segments decreased the texture value from 1080 to 1022 g force (fresh segments) and 1005 to 870 g force (dry segments). Naringin along with other bioactive compounds were retained to a greater extent in *Paranthas* containing dry pomelo fruit segments. *Paranthas* prepared using 20% (fresh) and 5% (dry) were sensorily acceptable. The pomelo incorporated *paranthas* had higher levels of resistance starch fractions (12.94%) with low predicted glycemic index (49.89%) compared to control *Paranthas* at 5.54 and 58.64% respectively. The fortified *paranthas* with an considerable content of bioactive compounds and low glycemic index indicate the possibility of using it as a dietary supplement. Thus utilization of pomelo fortification helps in improving the nutritional and functional property of *paranthas* suiting diabetes as well as general population.

Keywords Pomelo fruit segments · *Paranthas* · Bioactive components · Glycemic index

Introduction

Diabetes is a metabolic disorder of carbohydrate, protein and lipid metabolism that is specified by increased fasting and post-prandial blood sugar levels (Rang et al. 1991). Diabetes has affected worldwide ~ 415 million people in 2015 and is presumed to reach more than 642 million in the next 20 years (International Diabetes Federation 2015). Thus, it is necessary to look for an immediate and viable solution to prevent diabetes preferably by dietary and routine lifestyle modifications. The intake of whole grain diets with high dietary fiber content and low glycemic index (GI) helps in reducing the risk of diabetes (Hallfrisch and Behall 2000). The term GI was used in categorizing carbohydrate-rich foods based on their potential to raise/lower the postprandial blood glucose levels (Jenkins et al. 1981). The foods having low glycemic index with added dietary fiber, reduces postprandial glucose and insulin responses thereby improving blood glucose and lipid concentrations in healthy and diabetic populations (Fontvieille et al. 1992).

Nowadays, plant based foods are gaining importance to increase the per capita availability of foods (Sheela et al. 2004). Citrus fruits act as a rich source of dietary fiber and hence are recognized as essential components in healthy human life. In this regard, *Citrus maxima* (Burm.) Merr. (Pomelo) an indigenous plant of Malaya Island and east of India is an upcoming ‘functional food’ which may be of importance because of its nutritional and health benefits. *C. maxima* fruits which is rich in bioactive components is said to possess appetizing, cardiac stimulant and antitoxic property (Arias and Ramon-Laca 2005). Hence, these kinds of disease specific functional foods are getting awareness from the researchers worldwide.

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Wheat is a major cereal crop in India. It is the second largest producer of wheat in the world with about 12% share in total global wheat production (Shraddha et al. 2015). More than 80% of wheat produced in India is consumed in the form of traditional products such as *chapatti*, *roti*, *parantha* and *poori*. *Parantha* is a popular product of Indian origin prepared using whole wheat flour and is commonly known as flat bread. *Parantha* with the addition cereal, fruits and vegetables act as a functional food having essential nutrients and bioactive components (Dhingra and Jood 2001). The objective to this study was to evaluate the utility and substituting *paranthas* with pomelo fruit segments for its beneficial effects. Several studies have indicated the medicinal properties of *C. maxima*, but the nutritional and quality characteristics when incorporated into *parantha* have not been examined. In the present study, an attempt has been made to determine the physicochemical, sensory, bioactive components and glycemic indices of *parantha* supplemented with pomelo fruit segments. These findings would further help in familiarizing the pomelo fruit segments to be used as a supplementary ingredient in the diet to promote the health benefits of the consumers.

Materials and methods

The raw materials namely whole wheat flour (Aashirvaad Superior Atta, India), salt (food grade) and refined sunflower oil were procured from the local market for the study.

Pomelo fruit processing

The fruit of *C. maxima* (Burm.) Merr. (pomelo) was obtained from local market of Mysore, Karnataka, India during the month of February 2016. The fresh segments were separated from the fruit manually and dried in hot air oven at 53 ± 2 °C for 6 h to obtain dry fruit segments having ~ 5% moisture content.

Parantha making quality

Paranthas were prepared from whole wheat flour by incorporating fresh (10, 20 and 30%) and dry (2.5, 5 and 7.5%) pomelo fruit segments (Sudha et al. 2015). Ingredients (whole wheat flour, pomelo fruit segments, salt, oil and water) were mixed in a mixer for 5 min and rested for 10 min. Twenty five grams dough was sheeted into a circular shape with 14.8 cm (diameter) and 2 mm thickness. One gram of oil was smeared, folded into a half circle and then into a triangular shape of 2 mm thickness. The sheeted dough was baked on a preheated hotplate for 2 min at 180

°C by applying oil on both sides. *Paranthas* were cooled at room temperature and packed in polypropylene bags till further evaluation.

Paranthas were evaluated for shearing strength using Warner–Bratzler probe of texture analyzer (Model TAHDi, Stable Micro System, Surrey, UK) with load cell 10 kg and plunger speed at 100 mm/min. The *paranthas* prepared using various concentrations of pomelo fruit segments were evaluated for lightness (L^*), greenness ($-a^*$), yellowness ($-b^*$) and color difference (ΔE) using Hunter Lab Color Measuring system (Color Flex-EZ Hunter Lab, USA).

The product was evaluated by the panelists on 9 point hedonic scale. The quality characteristics of *parantha* enriched with pomelo fruit segments were assessed based on color, appearance, pliability, layers and texture. A combined score of all the five quality attributes was taken as the overall quality score.

Preparation of *parantha* sample for estimations

The prepared *paranthas* were dried in hot air oven at 48 ± 2 °C for 6 h. The dried *paranthas* were cooled at room temperature, homogenized and stored in polypropylene bags at refrigerated condition. Further the dried refrigerated samples were taken to room temperature before analysis.

Total sugars

The total sugar content was determined by the method described by Albalasmeh et al. (2013). The sample (10 μ L) was initially mixed with 5% phenol (300 μ L) and concentrated sulfuric acid was slowly added to the mixture. The test tubes were cooled and absorption was read at 490 nm. The total sugar content of the sample was expressed equivalent to mg glucose/g sample.

Reducing sugars

The reducing sugar estimation was carried out using the modified method of Miller (1959). To a 1 mL of reaction, 150 μ L of sample and 1 mL of DNS reagent was added. The tubes were placed in boiling water bath for 10 min and cooled at room temperature. Each solution was then diluted with 2 mL of water, mixed thoroughly and absorbance was recorded at 540 nm with the spectrophotometer (Thermospectronic, Germany). Total reducing sugar content of the sample was expressed equivalent to mg glucose/g sample.

Total phenolic content

Total phenolic content (TPC) in *paranthas* was evaluated using a modified colorimetric method described by

Henríquez et al. (2010). The reaction mixture was prepared by adding sample (100 μ L), Folin-Ciocalteu reagent (1.0 mL) and 10% sodium carbonate solution (2.0 mL). The tubes were incubated for 60 min at room temperature and the absorbance was detected at 765 nm using an UV–Vis spectrophotometer. The total phenolic content was expressed equivalent to mg Gallic acid/g sample.

Flavonoids

Flavonoids were estimated by a modified method of Lallianrawna et al. (2013). The sample (0.9 mL) with 75 μ L of 5% sodium nitrite solution was added and incubated for 5 min. Further 10% aluminum chloride (150 μ L) followed by 0.5 mL of 1 M NaOH was added and absorbance was recorded at 510 nm. The flavonoid content of the sample was expressed as the mg equivalent to catechin/g of sample.

Carotenoids

The experiment was carried out by the modified procedure of Carvalho et al. (2012). The sample (1 g) was homogenized in the dark (to avoid photolysis of carotenoids) with 20 mL of acetone. The filtrate was further extracted with petroleum ether and mixed well. The petroleum ether layer (upper layer) containing the carotenoids was collected separately. Sodium sulphate was added to remove excess moisture in the petroleum ether layer. The final volume of the petroleum ether fraction was noted. The absorbance was read in a spectrophotometer at 450 nm using petroleum ether as blank.

$$\text{Carotenoids content } (\mu\text{g/g}) = \frac{A \times V(\text{mL}) \times 10^4}{A_{1\%}^{1\text{cm}} \times P(\text{g})}$$

where A absorbance, V total extract volume, P sample weight, $A_{1\%}^{1\text{cm}}$ 2592 (β -carotene extinction coefficient in petroleum ether).

Naringin content

The paranthas were analyzed for the presence of naringin (bioactive compound) content using Shimadzu Class—VP HPLC model used with SPD-10AVP (PDA detector). One gram of the sample was extracted in methanol for 30 min. The supernatant was passed through 0.45 mm syringe filter and subjected to HPLC (Pichaiyongvongdee and Haruenkit 2009). Supelco C₁₈ (5 μ m) column (15 cm $\times$ 4.6 mm id), Supelco, USA was used with the mobile phase consisting of water: acetonitrile (80:20 v/v). The flow rate was maintained at 1 mL/min, detection wavelength was 270 nm, injection volume was 20 μ L and the total run time

was 20 min. Quantification of the compound was evaluated by comparing the peak area with authentic standards.

Total starch (TS)

The total starch content in formulated *parantha* samples was determined enzymatically according to the method described by Goni et al. (1997). The sample (50 mg) was dispersed in 6 mL of 2 M KOH and homogenized for 30 min at room temperature. Sodium acetate buffer (0.4 M) with pH 4.75 and 60 μ L amyloglucosidase (A7095, Sigma-Aldrich Chemical Company, St Louis, MO, USA) was added to the suspension and incubated for 45 min at 60 °C in a controlled shaking water bath. Starch was represented as glucose which was measured using glucose oxidase-peroxidase (GOD POD) kit. Factor conversion (0.9) was used to convert glucose to starch.

Resistant starch (RS)

Resistant starch was estimated according to the modified method described by Goni et al. (1997). The sample (100 mg) was incubated with pepsin solution (20 mg; P7000, Sigma-Aldrich Chemical Company, St Louis, USA) for 60 min at 40 °C. The starch was further hydrolyzed by adding pancreatic α -amylase (10 mg/mL; A3176, Sigma-Aldrich Chemical Company, St Louis, USA) solution at 37 °C for 16 h with constant shaking. After centrifugation (3000g for 15 min), the pellet was separated from the supernatant and digested with 2 M KOH. The solutions (pellet and supernatant) were separately incubated with the enzyme amyloglucosidase for 45 min at 60 °C. The glucose content from the samples was measured using a glucose oxidase-peroxidase (GOD POD) reagent kit (K-GLOX, Megazyme Bray, Co. Wicklow, Ireland) at 510 nm against the reagent blank. RS was calculated as glucose and converted to starch by multiplying with the factor 0.9. The difference between TS and RS gives the digestible starch (DS) content from the sample.

Predicted glycemic index (pGI)

The predicted glycemic index was measured by the modified procedure of Goni et al. (1997). The ground sample (100 mg) was incubated with 200 μ L pepsin solution (100 mg/mL HCl-KCl buffer) at 40 °C for 1 h with constant shaking. Pancreatic α -amylase solution (3 U/5 mL tris-maleate buffer) was added to the mixture and incubated at 37 °C (with continuous shaking). Aliquots of 1 mL was taken separately at every 30 min till 3 h and placed in boiling water with continuous shaking for 5 min (in order to inactivate the enzyme reaction). Samples were kept in

the refrigerator (4 °C) after each inactivation until the end of incubation time (180 min).

The solution was further incubated with 60 µL of amyloglucosidase (300 U/mL) for 60 °C for 45 min with constant shaking. After incubation, volume was made upto 10 mL with distilled water, centrifuged and taken for glucose measurement.

The release of glucose at regular time interval was measured at 510 nm using GOD POD kit. The values were plotted on a graph and the area under the concentration-over-time curve (AUC) was determined using Sigmaplot 10.0 (Systat Software, San Jose, CA, U.S.A.). The hydrolysis index (HI) was calculated as the percentage of glucose released from the samples compared to that released from standard glucose (0–180 min). The predicted glycemic indices of the samples were determined based on the equation of Goni et al. (1997): $pGI = 39.71 + 0.549 HI$.

Statistical analysis

The data was statistically analyzed using Duncan's new multiple range test (DMRT) using GraphPad Prism software version 4.03 for Windows (San Diego, CA, USA) with different experimental groups to the completely randomized design with four replicates each as described by Steel and Torrie (1980) at $p < 0.05$.

Results and discussion

Quality characteristics of paranthas supplemented with pomelo fruit segments

The physical attributes of *paranthas* incorporated with different levels of fresh and dry pomelo fruit segments are

presented in Table 1. The substitution of fresh pomelo fruit segments showed a gradual increase in the weight (32.08–39.73 g) and length (14.50–14.93 cm) of the *parantha* after processing conditions. The incorporation of dry segments also showed an increase in weight (34.45–40.23 g) and length (14.53–15.16 cm) of the formulated *parantha*. Both the factors were higher in the *parantha* supplemented with dry pomelo fruit segments which is due to the incorporation of higher quantity of fruit segments in dried form. The color values of *paranthas* prepared using wheat flour fortified with different concentrations of pomelo fruit segments were recorded using Hunter Colour Meter (Table 1). It was found that with the increase in pomelo fruit segments, there was a decrease ($p \leq 0.05$) in brightness (L) value from 48.11 to 43.89 (fresh segments) and 47.71 to 40.33 (dry segments) indicating the darkening of the product. It has been demonstrated that higher level of polyphenol oxidase in wheat flour is found to be responsible for the darkening of wheat products like chapati and noodles (Abrol and Uprety 1970). The 'a' value of the formulated *paranthas* increased with the increasing amount of pomelo fruit segments from 5.94–7.50 (fresh) and 7.04–9.09 (dry) indicating the increase in the redness of the products which is mainly attributed from the incorporation of pomelo fruit segments. However, there was a considerable decrease in 'b' values from fresh (16.60–16.20) and dry (16.42–15.99) segments which may be due to the Maillard reaction between the sugar and amino acids (Yadav et al. 2009). It was observed that the color of the formulated *paranthas* showed a significant decrease ($p < 0.05$) in 'b' and 'L' value but increase in 'a' value (redness) with higher percentage of pomelo fruit segments (Fig. 1).

Table 1 Physical characteristics of *parantha* supplemented with fresh/dry pomelo fruit segments

Pomelo segments (%)	Weight (g)	Length (cm)		Surface colour			
		X axis	Y axis	L	a	b	dE
0	29.15 ± 0.49	14.26 ± 0.65	13.90 ± 0.89	49.87 ± 1.07	5.27 ± 0.13	16.69 ± 0.83	44.62 ± 0.84
<i>Fresh</i>							
10	32.08 ± 0.52	14.50 ± 1.16	14.16 ± 1.44	48.11 ± 0.60	5.94 ± 0.63	16.60 ± 0.65	47.45 ± 0.29
20	35.22 ± 0.27	14.46 ± 0.87	14.22 ± 0.87	45.67 ± 0.26	7.16 ± 0.51	16.37 ± 0.42	51.45 ± 0.44
30	39.73 ± 0.44	14.93 ± 1.21	14.53 ± 1.13	43.89 ± 0.80	7.50 ± 0.74	16.20 ± 0.10	50.11 ± 0.82
<i>Dry</i>							
2.5	34.45 ± 0.62	14.53 ± 1.09	15.26 ± 0.69	47.71 ± 0.98	7.04 ± 0.11	16.42 ± 0.34	45.43 ± 0.74
5.0	37.36 ± 0.81	14.83 ± 0.73	15.55 ± 0.87	44.51 ± 1.12	8.62 ± 0.66	16.03 ± 0.52	47.42 ± 0.39
7.5	40.23 ± 0.44	15.16 ± 0.93	15.67 ± 1.04	40.33 ± 1.01	9.09 ± 0.58	15.99 ± 0.34	47.78 ± 0.76

Values are mean ± SD (n = 4)

Fig. 1 Photograph of *paranthas* supplemented with fresh and dry pomelo fruit segments. Note: 0—denotes *paranthas* unsupplemented with pomelo fruit segments; 10, 20 and 30—denotes *paranthas* supplemented with fresh pomelo fruit segments; 2.5, 5.0 and 7.5—denotes *paranthas* supplemented with dry pomelo fruit segments. **a** fresh segments (uncooked), **b** fresh segments (cooked), **c** dry segments (uncooked), **d** dry segments (cooked)

Sensory evaluation

Sensory analysis was performed to find the level of incorporation of pomelo fruit segments in *parantha*. The analysis was carried out on 9-point hedonic scale (Table 2). The score for color and appearance reduced from 8.0 to 7.0 with the increase in the addition of pomelo fruit segments. The reduction in the color value might be due to the increased burn spots on the surface of *paranthas* that occurs due to non-enzymatic Maillard reaction (Jain et al. 2013). The pliability which indicate the hand feel in terms of softness significantly reduced in *parantha* supplemented with fresh pomelo fruit segments, whereas *parantha*

incorporated with dry segments scored similar to the control *parantha* ($p \leq 0.5$). A significant reduction in texture score was observed from 1169 g for control to 1022 (fresh) and 870 g force (dry) on addition of increasing levels of pomelo fruit segments respectively. This may be due to high dietary fibre content in pomelo fruit which helped in the reduction of shear force by diluting the gluten protein which makes the product more extensible and chewy. Eating quality reduced with the addition of increased level of pomelo fruit segments, thereby increasing the bitterness of *parantha*. It is evident from the data that the *paranthas* prepared by addition of pomelo fruit segments up to 20% (fresh) and 5% (dry) were acceptable in all sensory

Table 2 Sensory evaluation of *parantha* supplemented with fresh/dry pomelo fruit segments

Pomelo fruit segments (%)	Colour and appearance (9)	Tearing strength (9)	Pliability (9)	Aroma (9)	Texture (g force)	Eating quality (9)	Overall quality (9)
0	8.0a	8.0a	8.0a	8.0a	1169	8.0a	8.0a
<i>Fresh</i>							
10	8.0a	8.0a	8.0a	7.5b	1080	7.5b	7.5b
20	7.5b	7.5b	7.5b	7.0c	1049	7.0c	7.0c
30	7.0c	7.0c	6.5c	7.0c	1022	6.5d	6.5d
<i>Dry</i>							
2.5	8.0a	8.0a	8.0a	8.0a	1005	8.0a	7.5b
5.0	7.5b	8.0a	8.0a	7.5b	938	7.5b	7.0c
7.5	7.0c	8.0a	8.0a	7.5b	870	7.0c	6.5d

Values in the parentheses indicate maximum score; Values for a particular column followed by different letters differ significantly ($p < 0.05$); SEM—standard error of mean at 70 degrees of freedom

attributes by retaining the basic characteristics of pomelo fruit with bitterness to the palatable level. Further increase in the concentration of pomelo fruit segments, *paranthas* seems to be very sour and bitter which was not favorable for consumption.

Bioactive components

The bioactive constituents in the formulated *paranthas* ranged from 145.22 to 180.74 mg GAE/100 g for phenolics, 32.79 to 54.85 mg CE/100 g for flavonoids and 46.33 to 254.02 µg/100 g for carotenoids (Table 3). Since the developed product was prepared focusing diabetic subjects the level of total and reducing sugar were estimated. It ranged from 4.62 to 7.06 g/100 g and 3.19 to 4.33 g/100 g, respectively. The dry segments supplemented *parantha* showed higher retention of bioactive constituents compared to *paranthas* incorporated with fresh segments. As the concentration of pomelo fruit segments in *parantha* increased from 10 to 30% (fresh) and 2.5 to 7.5% (dry), the content of the above mentioned bioactive constituents also increased correspondingly. The bioactives (phenolics, flavonoids and carotenoids) are the potential source of natural antioxidants and also possess other biological properties such as inhibition of hydrolytic and oxidative enzymes, anti-inflammatory and against cancer and cardiovascular diseases (Münzel et al. 2010). Hence the presence of bioactive compounds in pomelo substituted *paranthas* helps in providing beneficial health effects.

Naringin (4, 5, 7-trihydroxyflavanone-7-rhamnoglucoside) is a bioflavonoid that is commonly found in grapefruit and other related citrus species. It was reported to possess potent antioxidant, anti-apoptotic, anti-diabetic and anti-inflammatory effects (Cui et al. 2012). Priscilla et al. 2014 have reported that naringin is the bioactive compound that dampens postprandial glycemic response

which in turn acts as complementary approach in the management of diabetes. Hence, naringin content in processed products was evaluated. The loss of naringin content was minimum with ~ 65% retention in fresh segment supplemented *parantha* and 75% retention in *parantha* supplemented with dry segments (Online Resource 1A). The retention percentage of formulated *parantha* was calculated with the amount of naringin content present in fresh and dry segments taken for product development (Online Resource 1B). Shen et al. (2012) reported that citrus flavonoids (naringin, hesperidin and nobiletin) act effectively against enzymes in starch digestion which potentially helps in the prevention of postprandial hyperglycemia by reducing the plasma glucose level.

Starch digestibility and predicted glycemic index

Based on sensory attributes of the products 20% fresh and 5% dry segments incorporated *parantha* were selected for further studies on in vitro starch digestibility. The total starch and its fractions, DS and RS in the product are shown in Table 4. The starch fraction profile differed according to the composition of the product. The TS content in the products ranged between 60.16–65.31%. Resistant starch (RS) content varied among products with a range of 5.54–12.94% on dry weight basis. Compared to control *parantha*, the supplemented *parantha* (fresh and dry) had significantly higher ($p \leq 0.05$) values for RS which significantly showed reduction in DS (54.62–52.37%) content. Between the two variations, *parantha* incorporated with dry segments (5%) showed better starch digestibility with higher RS (12.94%) that is significantly different from the other formulated *paranthas*. The elevated RS content may be due to the inhibition of α -amylase (enzyme), thereby limiting the release of glucose from the starch. Resistant starch helps in increasing the

Table 3 Bio-active components of *paranthas* supplemented with fresh/dry pomelo fruit segments

Sample	Sugars (g/100 g)	Reducing sugars (g/100 g)	Phenolics (mg GAE/100 g)	Flavonoids (mg CE/100 g)	Carotenoids (µg/100 g)
0	4.62 ± 0.55	3.19 ± 0.38	145.22 ± 0.55	32.79 ± 0.34	46.33 ± 0.93
<i>Fresh</i>					
10	5.32 ± 0.61	3.28 ± 0.65	150.36 ± 0.79	34.09 ± 0.96	77.16 ± 0.78
20	5.56 ± 0.58	3.54 ± 0.94	156.83 ± 1.05	36.68 ± 0.67	108.54 ± 1.06
30	6.00 ± 0.50	3.80 ± 0.88	163.42 ± 0.77	37.97 ± 0.75	150.22 ± 1.15
<i>Dry</i>					
2.5	5.82 ± 0.30	3.64 ± 0.36	158.11 ± 0.35	39.00 ± 0.73	126.01 ± 0.84
5.0	6.61 ± 0.39	3.96 ± 0.44	170.21 ± 0.68	48.35 ± 0.84	169.11 ± 0.66
7.5	7.06 ± 0.47	4.33 ± 0.72	180.74 ± 1.10	54.85 ± 0.88	254.02 ± 1.22

Values are mean ± SD (n = 4)

GAE gallic acid equivalent, CE catechin equivalent

Table 4 In-vitro starch digestibility and predicted glycemic index of pomelo fruit segments incorporated *parantha*

Pomelo fruit segments (%)	TS (%)	RS (%)	DS (%)	HI (%)	pGI (%)
0	60.16 ± 1.67	5.54 ± 0.97	54.62 ± 1.78	34.49 ± 1.54	58.64 ± 1.67
Fresh ^a	61.29 ± 1.96	6.75 ± 0.84	54.54 ± 2.13	26.33 ± 1.42	54.16 ± 1.39
Dry ^b	65.31 ± 1.24	12.94 ± 1.15	52.37 ± 1.44	18.56 ± 2.04	49.89 ± 1.35

Values are mean ± SD (n = 4)

TS total starch, RS resistance starch, DS digestible starch, HI hydrolysis index, pGI predicted glycemic index

^a– 20%; ^b – 5%

indigestible carbohydrate portion in small and large intestines which in turn reduces the rate of carbohydrate absorption (Yamada et al. 2005). Reader et al. (2002) reported that a food containing high levels of resistant starch help in reducing the postprandial hyperglycemia in diabetic populations.

The glycemic response for the formulated *paranthas* has been depicted in Table 4. The in vitro digestion rate was defined as the percentage of starch hydrolysis at different duration of time (Fig. 2). The hydrolysis index of the *paranthas* ranged from 34.49 to 18.56% and the predicted glycemic index of the formulated functional foods ranged from 58.64% (control *paranthas*) to 49.89% (5% pomelo supplemented *paranthas*). The released glucose contents of the *paranthas* were as follows: control > 20% pomelo supplemented *paranthas* > 5% pomelo supplemented *paranthas*. This was supported by the amounts of starch digestion fractions (Table 4). Studies have established that glycemic index of food in human is influenced by many factors like rate of digestion or absorption, nature of the starch granules and food processing (John and Vladimir 2004). The foods with high GI rapidly digest and increase the blood glucose level, while low-GI foods undergo slower but gradual release of glucose into the blood stream. As described previously, the pomelo fruit segments (rich in

the bioactive compound, naringin) aided in lowering the glycemic index by reducing the glucose level in plasma which result in a slower digestion of starch in the intestinal lumen and subsequently slower absorption of glucose in the portal and systemic circulation (Wolever et al. 1991). Recent studies have implicated that high glycemic index foods would increase in the risk of heart diseases and diabetes (Ford and Liu 2001). Hence, information on GI will help in developing functional foods for normal and diabetic populations.

Conclusion

In this study, attempt has been made to develop novel *paranthas* by substituting wheat with pomelo fruit segments. *Paranthas* prepared with 20% (fresh) and 5% (dry) pomelo fruit segments were sensorially acceptable. The bioactive components increased with the increasing concentration of pomelo fruit segments in *paranthas*. This indicate that pomelo fruit segments have higher potential to act as an functional ingredient in wheat based products. Further incorporation of pomelo fruit segments in *paranthas* delayed the starch hydrolysis and thus lowered the predicted glycemic index. Hence, the present study suggests that pomelo fruit segments can be used as an ingredient in several formulations which further facilitate in generating product with low glycemic index and nutritional benefits for normal and diabetic populations.

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Fig. 2 Rate of starch hydrolysis in *paranthas* supplemented with fresh/dry pomelo fruit segments

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