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A Tomato Pomace Enriched Gluten-Free Ready-to-Cook Snack's Nutritional Profile, Quality, and Shelf Life Evaluation

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Abstract: Attempts were undertaken to design a quick ready-to-cook gluten-free snack utilizing finger millet and potato flour (50:50) as well as tomato pomace due to the restricted availability of gluten-free snack goods in the Indian market. The nutritional content of the food and its general acceptability, cooking characteristics, and storage stability were all tested. The addition of tomato pomace had a distinct influence on the product's color and hardness. Additionally, it resulted in a significant reduction in the amount of oil used, cooking loss, and frying time required. With a high acceptance level, the snack supplemented with 10% tomato pomace was determined to be the most optimal formulation. When the same substance was subjected to FTIR analysis, it was discovered that it retained all the important functional groups required for sustaining antioxidant activity. It also displayed high storage stability, a desirable overall acceptance score, and a very promising nutritional profile, all of which would benefit the product's end users.

Keywords: tomato pomace; by-product utilization; finger millet; gluten-free; potato flour; convenience food

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1. Introduction

Tomato (*Solanum lycopersicum*), touted to be the most important vegetable crop, is consumed both in its fresh and processed forms. Its production in India amounted to 21.18 million metric tons in 2021 [1]. Tomato processing generates 1.5 to 5% pomace, which is a waste product but is a storehouse of nutrition [2,3]. It is used as animal feed or is dumped in landfills [4], thus having both economic and environmental implications since additional costs for transportation are required. Therefore, recycling and reusing pomace can reduce tomato processing costs [5].

Majority of the world population consumes wheat in one form or the other but in recent years, increasing number of people are showing sensitivity towards the gluten present in wheat, rye, and barley, which causes health problems for them [6]. The symptoms include fatigue, weight loss, diarrhea, and depression [7]. Since there is no cure yet for celiac disease, the only option is to have a gluten-free diet. Any food that contains less than 20 ppm (or 20 mg/kg) of gluten is defined by United States Food and Drug Administration (FDA) as gluten free [8]. Furthermore, not all consumers who prefer gluten-free food have celiac disease. Many switch to it as a matter of personal preference, to meet specific dietary requirements, as fasting food, or just to have healthy food [9,10]. Additionally, there is a change in eating patterns and individual preferences, and experimentative palates have resulted in the creation of new markets for ready-to-cook foods that effectively reduce drudgery, cooking time, and procurement of multiple ingredients while adding convenience

and variety to the meal [11]. Consumers perceive readymade frozen foods as nourishing, healthy, and delicious [12]. In this scenario, snacks have now become an important part of any diet and biting into a healthy snack serves both the purposes of convenience and nutrition. Besides being gluten-free, the snack should serve the dual purpose of being able to be indulged in as well as provide nutrition for wider acceptance. However, the availability of convenient gluten-free traditional snacks is very limited in the Indian market, and even if available, these are expensive [13].

Finger millet (*Eleusine coracana* L.) is the most consumed small millet in India and accounts for 85% of all millet produced in India [14]. It has an excellent nutritional profile compared to commonly consumed cereals [15–17]. Its crude fiber and mineral contents are markedly higher than those of wheat (1.2% fiber and 1.5% minerals) and rice (0.2% fiber and 0.6% minerals); its protein is relatively better balanced; and it contains more lysine, threonine, and valine than other millet. It has the highest calcium content among all cereals (344 mg/100 g), which is almost three times more than milk and tenfold higher than brown rice, wheat, or maize [17]. The total dietary fiber content of finger millet grain (19.1%) is reported to be the highest compared to that of many other cereal grains (12.1%, 3.7%, 12.8%, and 11.8%, respectively, for wheat, rice, maize, and sorghum) [16].

Despite the ample availability of tomato pomace as well as a healthy gluten-free alternative grain, there are not many products on the market to meet the demand for convenient gluten-free snacks due to the lack of optimized methods for their preparation. The utilization of tomato pomace in food products is challenging, owing to its highly perishable nature, acidity, and the lack of knowledge of how it affects the quality attributes of the prepared product.

The present study was hence undertaken with the purpose of developing a ready-to-cook gluten-free (RTC-GF) snack using finger millet and tomato pomace that has good acceptability and palatability and to study the nutritional traits and shelf-life of the product.

2. Materials and Methods

Fresh tomato pomace (variety: *Punjab Ratta*), devoid of any foul odor or taste, was obtained from the Food Industry and Business Incubation Centre, Punjab Agricultural University, Ludhiana. Immediately after procurement, it was dried in a tray dryer at 50 °C for 48 h and then milled in the mixer grinder (Inalsa Inox 1000 model) and sieved through 40 mm sieve to get a fine tomato pomace powder (TPP). The powder was packed in polyethylene bags and stored in a refrigerator at 4 ± 2 °C till further use.

More than 1500 germ plasm lines of finger millet were acquired by PAU, Ludhiana from NBPGR, New Delhi, due to the feasibility of its profitable cultivation in Punjab. After initial screening, a high yielding, stable, and promising line, IC0475677, was shortlisted for further testing. Seeds from this line were procured from the university's Department of Plant Breeding and Genetics, thoroughly cleaned and washed, and then dried at 60 ± 2 °C for 6 h in a tray dryer. They were milled to get finger millet flour (FMF) using a Laboratory Mill 3303 (Perten Instruments), sieved through a 40 mm sieve, packed in polyethylene bags and stored in a refrigerator at 4 ± 2 °C till further use.

Potato flour (PF) was prepared by the standard procedure, where the potatoes are washed, peeled, diced, boiled, dried in a cabinet drier at 50 °C, ground, sieved, and packed in airtight containers [18]. Fresh ginger, garlic, green chilies, and coriander, along with salt, spices, and refined soybean oil, were procured from the local market.

2.1. Product Preparation

In the initial trials, FMF was used either as a powder (after roasting in an open pan with continuous stirring till a toasty aroma emanated) or as a cooked paste (by cooking the flour in four times water to obtain a thick gruel here called finger millet paste (FMP)). It was found that the addition of finger millet as a cooked paste gives a product with better handling, binding, pliability, and texture, and the paste was hence chosen to be added in the final formulation. Sensory experiments showed that the finger millet paste (FMP) can

be substituted with up to 50% of PF to get the best sensory scores [19]. A mixture was prepared containing 30% finely chopped onion, 15% crushed ginger, 10% crushed garlic, 10% green chili, 15% green coriander, 15% salt and 5% garam masala spice mix and it was added in each formulation. The base formulation of the RTC-GF snack contained FMP and PF in equal proportions. This represented the control sample (T1) in which there was no addition of TPP, but the spice mixture was added. Further experiments were done to standardize the addition of TPP to ascertain its maximum utilization without impairing the quality of the product. The TPP was substituted in the mix at 0, 5, 10, 15, 20, and 25% levels to obtain sample T1, T2, T3, T4, T5, and T6, respectively. The various treatments and their formulations are tabulated under Table 1.

Table 1. Formulations of the various treatments for one kg mix of RTC-GF snack.

Treatments (% of TPP)	TPP(g)	FMP + PF (1:1) (g)	Spice Mixture(g)
T1 (0%)	0	950	50
T2 (5%)	47.5	902.5	50
T3 (10%)	95.0	855.0	50
T4 (15%)	142.5	807.5	50
T5 (20%)	190.0	760.0	50
T6 (25%)	237.5	712.5	50

The product was prepared by following the procedure as given by Rehal et al. [19] and the pictorial representation of the same is given in Figure 1. The RTC-GF snack was analyzed for its various cooking attributes and sensory evaluation (as per details given in the Sensory Evaluation section). The formulation which was found most acceptable by the panelists and which would enable the maximum utilization of TPP was selected for conducting storage studies and nutritional status. The most acceptable formulation was then prepared, flash-fried, cooled, and packed in LDPE and HDPE pouches, and stored at −20 °C. These were analyzed for various quality characteristics like free fatty acids, peroxide value, and sensory evaluation after 0, 15, 30, 45, 60, 75, and 90 days of frozen storage by finish-frying the product immediately after taking it out of frozen storage as conducted by Rehal et al. [19].

2.2. Physico-Chemical Analysis

The moisture, protein, fat, ash, and fiber content of the raw materials as well as of the RTC-GF snack were determined as per the method prescribed by AOAC [20]. Total carbohydrates were estimated by the difference method, as in Yadav et al. [21]. The energy content in kcal/100 g was calculated as per Sehgal et al. [11]. For mineral estimation, one gram of sample was digested in a combination of nitric acid and perchloric acid (3:1), made up to a volume of 50 mL using deionized water. The minerals present in it were then estimated by plasma atomic emission spectrometry (Thermo Scientific, Waltham, MA, USA), as shown by Kaur et al. [22], where the samples were digested using a di-acid mixture, made up to the required volume with deionized water, filtered, and then further used for estimation. The amino acid analysis was carried out according to the method given by Musaalbakri et al. [23]. The estimation was done using HPLC, undertaking the hydrolysis of the protein with 6 M HCL containing 0.1 per cent phenol 110 °C for 24 h. Methionine was determined after pre-hydrolysis with performic acid oxidation before HPLC analysis, whereas tryptophan was determined by alkaline hydrolysis. Amino acids were expressed as g/100 g.

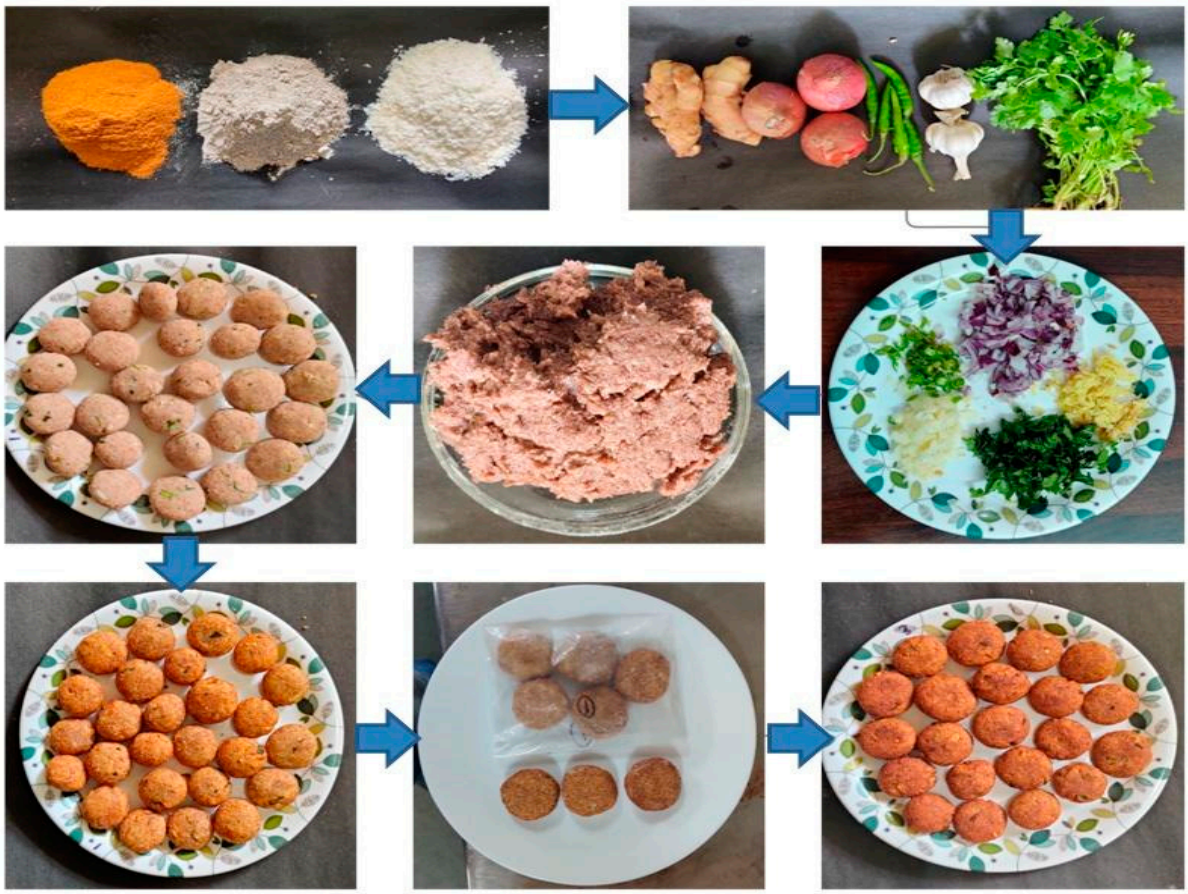


Figure 1. Process for Preparation of RTC-GF Snack.

The samples were analyzed for fatty acid composition by gas liquid chromatograph (model 7820A series, Agilent Technologies, Palo Alto, CA, USA) equipped with a flame ionization detector with a CP-Sil 88 (25 m × 0.25 mm × 0.20 mm) FAME column. The temperature of the oven, detector, and injector were maintained at 210, 240, and 230 °C, respectively. Two µL of the sample were injected at a split rate of 10:1. Individual fatty acids were expressed as a percentage of total fatty acids, according to Hassanien et al. [24].

The color of the RTC-GF was determined in terms of L*, a*, and b* values where L* measured lightness ranging from black (L = 0) to white (L = 100), a* measured red (+) or green (-), and b* measured yellow (-) or blue (-) using a Minolta spectrophotometer colorimeter (ModelCM-508d). Hue angle (h°) and chroma (C) were measured as per Singh et al. [25].

2.3. Phytochemical Analysis

Lycopene was extracted and quantified by following the methods given by Ranganna [26] and Rodriguez-Amaya and Kimura [27]. The phenolic compounds were extracted by refluxing 50 mL of 80% *v*/*v* aqueous ethanol for 3 h at 40 °C and then total phenolic content (TPC) was determined as per the procedure given by Tapia-Salazar et al. [28]. The total flavonoids content (TFC) was determined by the aluminum chloride colorimetric method given by Zhishen et al. [29] and the results were expressed as quercetin equivalent (QE) mg/100 g db.

2.4. Antioxidant Analysis

The antioxidant activity of the samples was evaluated by preparing the extract of the samples. The weighed sample (one gram) was refluxed twice with 80% acidified methanol for 3 h. The pooled extracts were centrifuged at 1600× *g* for 10 min (Sorvall ST 16R, Thermo

Fischer Scientific, Bremen, Germany), with the volume made up with aqueous methanol, and these extracts were stored in amber bottles at 4 ± 1 °C till further analysis.

The DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging activity was measured by using the method given by Herrara-Balandrano et al. [30]. The ferric reducing antioxidant power (FRAP) assay was performed as per the method given by Silva et al. [31] and the results are given as µmol ferrous sulphate equivalent (FSE)/100 g db. The 2′-azinobis-3-ethylbenzthiazoline-6-sulfonic acid (ABTS) radical scavenging activity was determined according to the method of Udeh et al. [32] and the results were expressed as µmol Trolox equivalent (TE)/100 g. The ability to chelate ferrous ions was determined to elucidate the metal chelating activity (MCA) by following the method detailed by Jayawardena et al. [33] and the MCA was reported in percentage (%).

2.5. Cooking Analysis

Cooking loss (%) was determined by taking the weight difference between raw and fried snacks. The frying time (secs) was noted as the time needed for the product to achieve a desirable reddish-brown color associated with fried foods. The oil uptake (%) was calculated by estimating the initial and final fat content and mass, before and after frying, of the product and computing the values using the equation given by Garmakhany et al. [34]. The texture profile analysis was carried out using a TA-XT texture analyzer (Stable Micro Systems Model TA-HDi, Surrey, UK) with an SMS P/5 probe to evaluate the crust hardness, where the hardness value is taken from where the peak force occurs during the first compression [35].

2.6. Sensory Evaluation

The evaluation of the sensory characteristics of the RTC snack were carried out through a semi-trained panel aged 24–58 years on a 9-point hedonic scale. The samples were coded (using different alphabet combinations) before being presented, and water was provided to rinse the mouth in between different samples. The panel scored the product for appearance, taste, flavor, texture, and overall acceptability.

2.7. Fourier-Transform Infrared (FTIR) Spectroscopy

Spectra of the finished product were taken on FTIR-ATR (Thermo Nicolet 6700 FTIR) spectrometer with attenuated total reflection (ATR) mode. A pinch of powdered sample was placed on the FTIR sample holder, and the spectrum was taken in the mid infra-red (IR) region (600–4000 cm^{-1}) [36].

2.8. Storage Studies

Free fatty acids (FFA%) such as oleic acid, peroxide value (PV), and moisture content were determined following standard protocols [20] and sensory studies of the optimized product (by the method given under sensory evaluation) were carried out every 15 days.

2.9. Statistical Analysis

The data were expressed as mean ± standard deviation (SD) (ten replicates for sensory analysis, three for others). The results were then subjected to analysis of variance (ANOVA) followed by Duncan multiple comparison test with $p \leq 0.05$ significance level using SPSS 18.0 statistical software.

3. Results

3.1. Physico-Chemical, Phytochemical, and Antioxidant Analysis

The proximate composition of the major raw materials (Table 2) shows that TPP has the highest amount of protein, followed by FMF and PF. A similar trend was observed for fat, ash, and crude fiber content of the raw materials whereas the reverse trend was observed for total carbohydrate content, with potato flour having the highest and TPP having the lowest carbohydrate content.

Table 2. Physico-chemical and phytochemical composition of major raw materials.

Parameter	Finger Millet Flour	Tomato Pomace Powder	Potato Flour
Moisture content (%)	8.56 ± 1.02 ^{a}	5.96 ± 1.12 ^{b}	6.08 ± 0.91 ^{ab}
Protein (%)	8.10 ± 0.90 ^{b}	14.95 ± 0.80 ^{a}	2.84 ± 1.01 ^{c}
Fat (%)	1.86 ± 0.18 ^{b}	8.52 ± 0.32 ^{a}	0.11 ± 0.11 ^{c}
Ash (%)	2.47 ± 0.21 ^{b}	4.27 ± 0.22 ^{a}	1.89 ± 0.15 ^{c}
Total carbohydrates (%)	79.01 ± 0.20 ^{b}	66.3 ± 0.21 ^{c}	89.09 ± 0.36 ^{a}
Crude fiber (%)	3.61 ± 0.87 ^{b}	39.45 ± 0.86 ^{a}	1.80 ± 0.73 ^{c}
TPC (mg GAE/100 g)	320 ± 1.10 ^{a}	179.67 ± 0.92 ^{b}	42.47 ± 0.87 ^{c}
TFC (mg QE/100 g)	56.11 ± 0.51 ^{b}	68.77 ± 0.57 ^{a}	6.20 ± 0.09 ^{c}
DPPH radical scavenging activity (%)	70.08 ± 0.3 ^{a}	52.41 ± 0.40 ^{b}	18.70 ± 0.32 ^{c}
FRAP (µmol FSE/100 g	2231.19 ± 15.6 ^{a}	1129.03 ± 7.9 ^{b}	584.15 ± 4.2 ^{c}
ABTS (µmol TE/100 g	913.01 ± 7.2 ^{a}	609.26 ± 4.0 ^{b}	33.19 ± 0.26 ^{c}
MCA (%)	58.25 ± 0.47 ^{a}	41.98 ± 0.36 ^{b}	18.73 ± 0.21 ^{c}
Calcium (mg/100 g)	274.3 ± 0.02 ^{a}	76.4 ± 0.01 ^{b}	67.2 ± 0.02 ^{c}
Phosphorus (mg/100 g)	295.7 ± 0.03 ^{a}	219.7 ± 0.02 ^{b}	59.30 ± 0.02 ^{c}
Magnesium (mg/100 g)	119.1 ± 0.01 ^{b}	126.7 ± 0.04 ^{a}	19.43 ± 0.01 ^{c}
Sodium (mg/100 g)	35.9 ± 0.01 ^{c}	129.1 ± 0.03 ^{a}	40.12 ± 0.03 ^{b}
Potassium (mg/100 g)	257.6 ± 0.02 ^{c}	1011.5 ± 0.04 ^{a}	532.6 ± 0.03 ^{b}
Iron (mg/100 g)	3.61 ± 0.03 ^{b}	9.26 ± 0.02 ^{a}	2.79 ± 0.01 ^{c}
Zinc (mg/100 g)	2.55 ± 0.04 ^{b}	3.46 ± 0.03 ^{a}	1.36 ± 0.02 ^{c}

Values are mean ± SD, n = 3; values within a row with different superscripts are significantly different ($p \leq 0.05$).

FMF showed a total phenolic content (TPC) of 320 mg GAE/100 g, which is significantly higher than that of TPP (179.67 mg GAE/100 g) and PF (42.47 mg GAE/100 g). The DPPH radical scavenging activity also followed a similar trend. Amongst minerals, calcium and phosphorus were found in higher amounts in FMF whereas magnesium, sodium, potassium, iron, and zinc were more prominent in TPP. Potato flour had significantly lower amounts of the estimated minerals amongst the raw materials.

Statistical analysis shows that the addition of TPP has a defined effect on the color values of the RTC-GF snacks (Figure 2). The control sample reported the highest L* values which decreased successively with the increase in percentage of TPP. It was observed that the supplementation beyond 15% had no significant effect on the L* values. The a* values, which depict the redness of the product, show a significant difference ($p \leq 0.05$) with a gradual increase. The addition of tomato pomace resulted in the decreased yellowness of the RTC-GF snack, which is reflected by lower b* values but the supplementation beyond 15% exhibited no significant difference ($p \leq 0.05$) in the b values. The hue angle ranged from 73.29° to 33.47° for T1 and T5, respectively, while the chroma values ranged from 22.40 to 18.53, where T3, T4, and T5 were not significantly different from each other ($p \leq 0.05$).

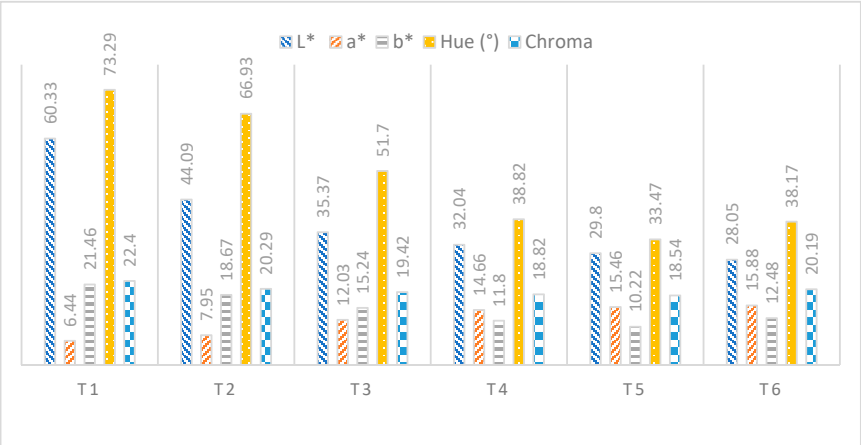


Figure 2. Color Scores of Ready-to-cook Gluten-free Snacks.

3.2. Cooking Analysis

The frying time of the RTC-GF snack showed a successive decrease from 42.41 s for sample T1, which contained no TPP, to 30.18 s in sample T5, which had 25% TPP. The hardness value of the control sample without TPP (T1) was 34.88 N which falls to 22.54 N due to the addition of 5% TPP (T2) but showed a continuous increase up to 36.6 N with an increase in the supplementation of TPP up to 25% (Figure 3a). Moreover, T1, which was made without the addition of TPP, exhibited the highest cooking loss (15.04%) and oil uptake (13.99%) amongst all the samples. These parameters showed a decrease in the samples as the concentration of TPP increased in T2 to T6 from 5 to 25% (Figure 3b). The oil uptake was found to be 7.42% while the cooking loss was as less as 6.73% in sample T6.

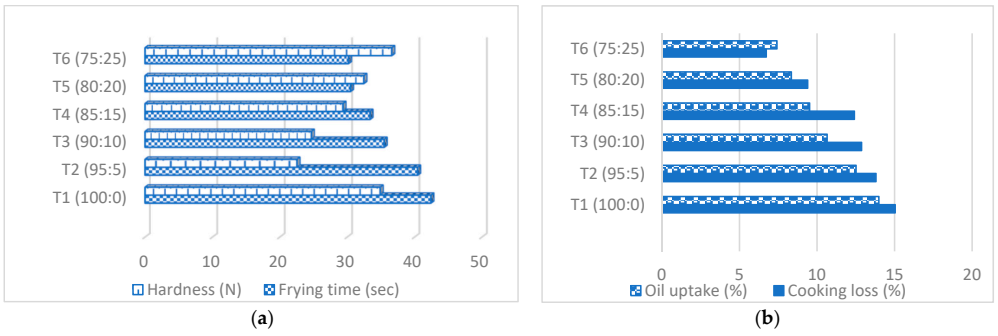


Figure 3. Cooking analysis: (**a**) Effect of addition of tomato pomace powder on the frying time and hardness of ready-to-cook gluten-free snack; (**b**) Effect of addition of tomato pomace powder on the oil uptake and cooking loss of ready-to-cook gluten-free snack.

3.3. Sensory Analysis

Figure 4 depicts the results of the sensory analysis of the RTC-GF snack, from where it is evident that the supplementation with TPP up to 25% has a profound effect on all the sensory parameters of the snack. In the case of taste, the scores showed a significant increase with up to 10% supplementation but beyond 20%, there was a significant decline in the scores for taste. A non-significant effect was observed for flavor at 0%, 5%, and 20% supplementation levels. There was a significant difference in 10% and 25% supplementation with TPP with regard to the flavor scores, with 10% obtaining the maximum score in all. The texture scores increased successively as the supplementation of TPP increased up to 10%, after which a significant decrease in the scores was observed with the increase in the levels of TPP. The snack with 10% of tomato pomace showed maximum overall acceptability due to the highest scores in appearance, taste, and texture, which were significantly higher than any other levels of supplementation. However, the snack having up to 20% supplementation level with tomato pomace also exhibited average sensorial attributes, but beyond that level, the overall acceptability scores declined.

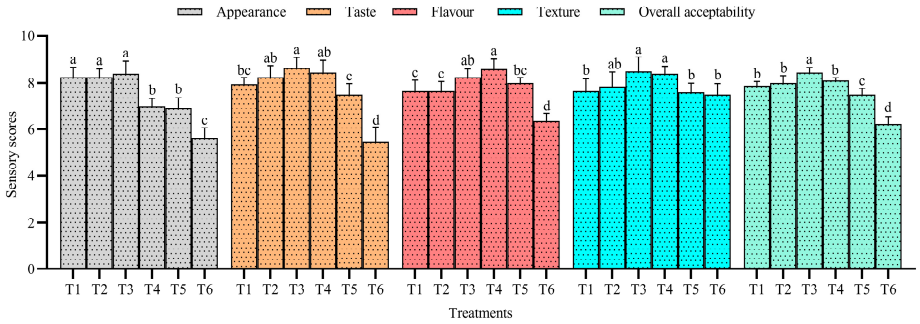


Figure 4. Sensory scores of the various formulations of ready-to-cook gluten-free snack. (Values are mean ± SD, n = 10; values within an attribute with different superscripts are significantly different ($p \leq 0.05$)).

3.4. Fourier-Transform Infrared (FTIR) Spectroscopy

Figure 5a–c presents the FTIR spectra of the finished RTC-GF snack, TPP, and FMF. Dominant peaks were observed at 2925 and 2855 cm^{-1} in all three spectra. The stretching areas were observed at 1376–1378 cm^{-1} in the FMF as well as RTC-GF snack. Absorption bands were observed at 1011.3, 1030.7, and 1012.6 cm^{-1} in the RTC-GF snack, TPP, and FMF, respectively. Similarly, peaks were also observed at a wavelength of 1744–1745 cm^{-1} as well as 2854–2856 cm^{-1} in all three spectra. The presence of absorption bands in the wavelength of 3290 to 3320 cm^{-1} were also found to be present in all the three commodities, *viz.*, FMF, TPP, and RTC-GF (T3).

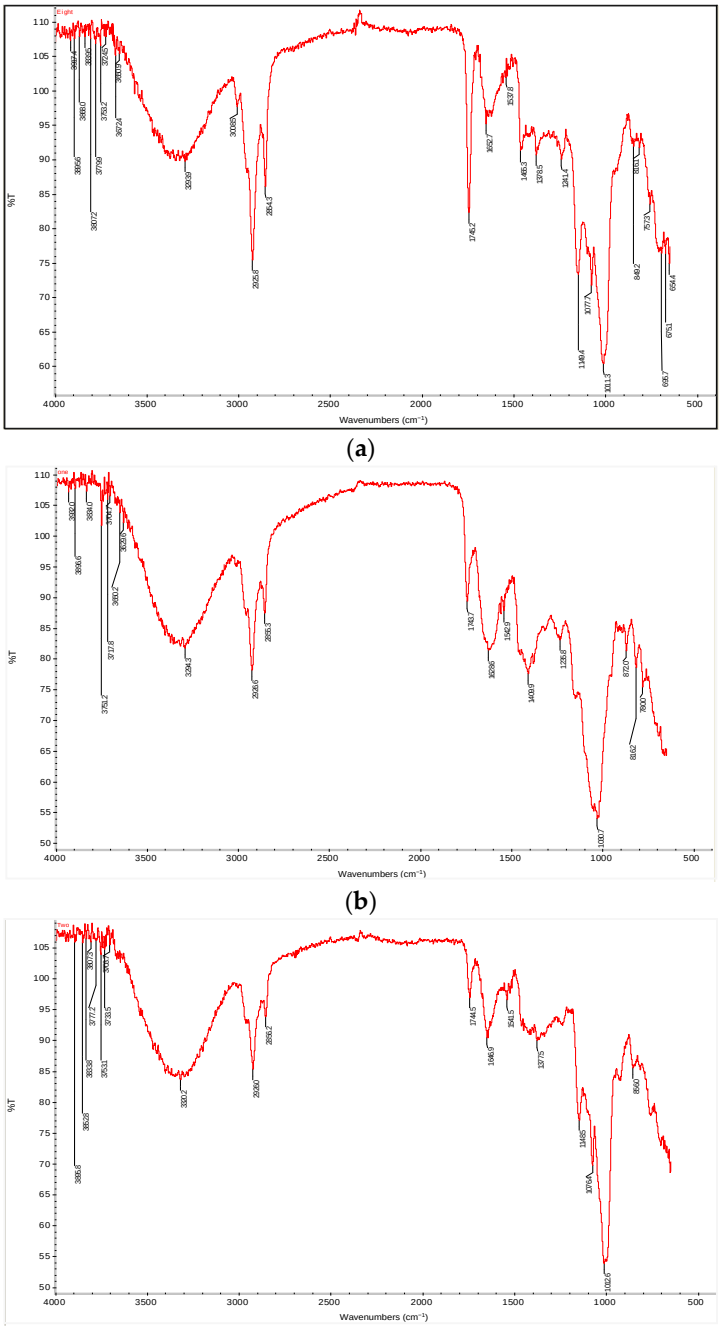


Figure 5. (**a**) FTIR spectrum of finished fried ready-to-cook gluten-free (T3) snack. (**b**) FTIR spectrum of tomato pomace powder. (**c**) FTIR spectrum of finger millet flour.

3.5. Nutritional Profile of the Product

The nutritional profile of the control RTC-GF snack containing no TPP (T1) and having 10% TPP (T3) is tabulated under Table 3. The enriched product provides a protein, fat, carbohydrate, and crude fiber content of 6.9%, 11.48%, 34.52%, and 5.2%, respectively, along with 248.2 kcal/100 g energy. The energy content of T3 is significantly less than the T1 sample containing no TPP. The TPC content is 186 mg GAE/100 g in T3 which was significantly higher than T1 (151.2 mg GAE/100 g). Similarly, the TFC also exhibited similar trend. The T3 had lycopene content of 5.08 mg/100 g while this was not detected in the T1 sample. The antioxidant activity as estimated by DPPH radical scavenging activity, FRAP, ABTS, and MCA for the RTC-GF snack shows significantly enhanced activity in the T3 sample as compared to T1. Potassium is the most abundant mineral present in the T3 RTC-GF snack followed by phosphorus, calcium, magnesium, sodium, iron, and zinc whereas T1 had amounts of phosphorus (206 mg/100 g) significantly higher than T3. Oleic acid is the most dominant fatty acid (52.1%) in T3, followed by linoleic acid (24.2%) and palmitic acid (22.8%), while T1 contains significantly higher amounts of palmitic acid as well as stearic acid. Amongst the essential amino acids, tryptophan is the highest (5.6%), followed by valine, phenyl alanine, isoleucine, and others in T3. It was observed that except for valine and leucine all other essential amino acids were present in significantly higher amounts in the T3 sample as compared to T1. The ω6/ω3 ratio was less for the T3 sample.

Table 3. Nutritional profile of ready-to-cook gluten-free snack (T1 (control) and T3).

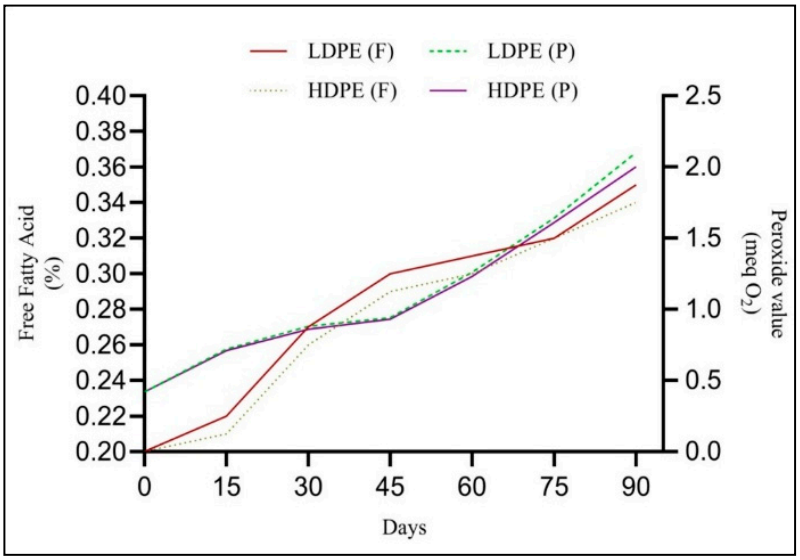
Parameter	T1	T3	Parameter	T1	T3
Moisture content (%)	40.5 ± 0.60 ^{b}	43.4 ± 2.6 ^{a}		Fatty acids (%)	
Protein (%)	5.01 ± 0.06 ^{b}	6.9 ± 0.16 ^{a}	Oleic acid	55.2 ± 0.82 ^{a}	52.1 ± 0.69 ^{b}
Fat (%)	17.45 ± 0.26 ^{a}	11.48 ± 0.70 ^{b}	Linoleic acid	25.6 ± 0.39 ^{a}	24.2 ± 0.29 ^{b}
Ash (%)	2.07 ± 0.27 ^{b}	3.7 ± 0.22 ^{a}	Linolenic acid	2.3 ± 0.02 ^{b}	3.4 ± 0.38 ^{a}
T. carbohydrates (%)	32.80 ± 0.51 ^{a}	34.52 ± 1.88 ^{a}	Palmitic acid	25.9 ± 0.37 ^{a}	22.8 ± 0.04 ^{b}
Crude fiber (%)	2.17 ± 0.25 ^{b}	5.2 ± 0.11 ^{a}	Stearic acid	6.2 ± 0.12 ^{a}	4.1 ± 0.52 ^{b}
TPC (mg GAE/100 g)	151.2 ± 2.01 ^{b}	186 ± 9.1 ^{a}	ω6/ω3	12.43: 1	7.1:1
TFC (mg QE/100 g)	31.06 ± 0.27 ^{b}	36.79 ± 0.30 ^{a}			
Lycopene (mg/100 g)	-	5.08 ± 0.09			
DPPH (%)	33.7 ± 0.64 ^{b}	46.7 ± 2.1 ^{a}			
FRAP (µmol FSE/100 g	1427.63 ± 9.9 ^{b}	1442.78 ± 10.11 ^{a}			
ABTS (µmol TE/100 g	537.11 ± 4.1 ^{b}	584.39 ± 4.4 ^{a}			
MCA (%)	40.70 ± 0.30 ^{b}	41.48 ± 0.34 ^{a}		Essential AAS (%)	
	Minerals		Valine	5.0 ± 0.10 ^{a}	5.2 ± 0.11 ^{a}
Calcium (mg/100 g)	152.6 ± 2.59 ^{b}	160 ± 1.01 ^{a}	Leucine	3.6 ± 0.08 ^{a}	3.5 ± 0.06 ^{a}
Phosphorus (mg/100 g)	206 ± 3.29 ^{a}	187 ± 1.60 ^{b}	Isoleucine	3.0 ± 0.06 ^{b}	4.53 ± 0.07 ^{a}
Magnesium (mg/100 g)	71.3 ± 0.78 ^{b}	89 ± 0.91 ^{a}	Threonine	3.4 ± 0.07 ^{b}	4.3 ± 0.06 ^{a}
Sodium (mg/100 g)	33.2 ± 0.53 ^{b}	40 ± 0.59 ^{a}	Methionine	2.9 ± 0.05 ^{b}	3.1 ± 0.04 ^{a}
Potassium (mg/100 g)	356.2 ± 5.69 ^{b}	407 ± 6.02 ^{a}	Lysine	3.1 ± 0.08 ^{b}	4.2 ± 0.06 ^{a}
Iron (mg/100 g)	2.79 ± 0.03 ^{b}	3.3 ± 0.06 ^{a}	Phenyl alanine	4.0 ± 0.12 ^{b}	5.1 ± 0.08 ^{a}
Zinc (mg/100 g)	1.82 ± 0.02 ^{b}	2.1 ± 0.03 ^{a}	Histidine	2.05 ± 0.03 ^{b}	2.2 ± 0.03 ^{a}
Energy (kcal/100 g)	308.29 ± 4.2 ^{a}	248.2 ± 5.3 ^{b}	Tryptophan	2.4 ± 0.04 ^{b}	5.6 ± 0.10 ^{a}

Values are mean ± SD, n = 3; values within a row with different superscripts are significantly different ($p \leq 0.05$).

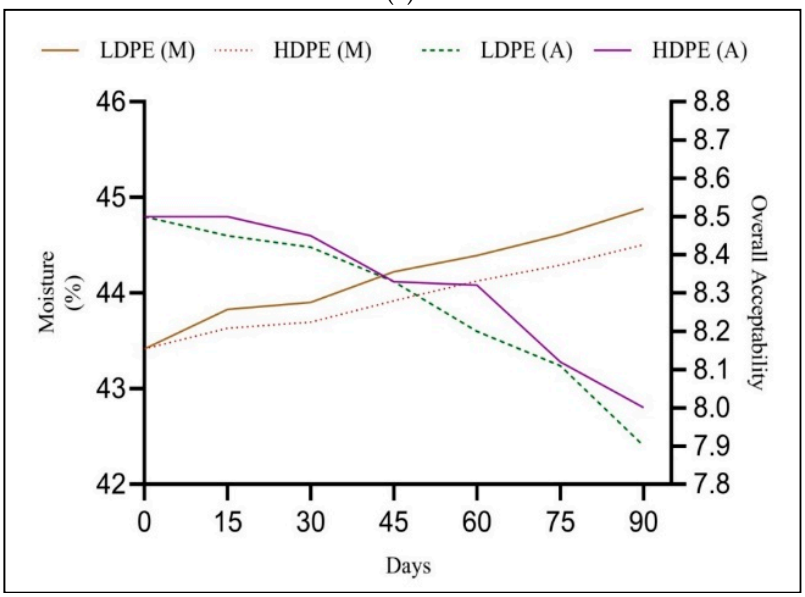
3.6. Storage Studies

Figure 6 shows the effect of frozen conditions on the RTC-GF snack. It is evident from Figure 6a that the free fatty acid content and peroxide value showed a steady increase in both the packaging materials but more so when the product was stored in LDPE than in HDPE pouches. The fresh samples had a free fatty acid content of 0.952% and the peroxide value was 0.42 meqO_2. The free fatty acid concentration increased to 1.197% for the snack in LDPE pouches and 1.175% in HDPE pouches after 90 days of storage. For the same time period, the peroxide value of the sample increased to 2.0 meqO2 in HDPE and 2.01 in LDPE pouches. Figure 6b represents the moisture content and overall acceptability of the

RTC-GF snack during its storage. The fresh product had a moisture content of 44.882%. It is evident that the moisture content of the stored product increased to 43.414% in LDPE and 44.505% in HDPE pouches after 90 days of storage. Regarding the sensory analysis of the product during storage, the overall acceptability scores decreased from 8.5 for fresh product to 7.9 for the snacks in LDPE pouches and 8.0 for the product in HDPE pouches on the 90th day of the storage study.



(**a**)



(**b**)

Figure 6. Storage studies: (**a**) Effect of packaging material on the free fatty acid content and peroxide value of stored ready-to-cook gluten-free (T3) snack; (**b**) Effect of packaging material on the moisture content(M) and overall acceptability(A) of stored ready-to-cook gluten-free (T3) snack.

4. Discussion

Of all the raw materials, tomato pomace powder (TPP) contained the highest fat, ash, and crude fiber content. The total phenolic content (TPC) was maximum for finger millet flour (FMF), followed by TPP and potato flour (PF) while TPP had the maximum total flavonoid content (TFC). The same pattern was observed for the DPPH radical scavenging activity. TPP retains its bioactive potential even after the tomatoes have undergone processing [3,37]. TPP also has maximum content of iron and zinc, while FMF is a rich source

of minerals, especially calcium, phosphorus, potassium, and magnesium. An estimated 17.3% of the world population is at risk of inadequate zinc intake [38] which is important for the immune system and metabolic activities. A combination of these raw materials in product development will help to meet the requirements of these micronutrients, which have established implications in various metabolic processes and health benefits, in diet.

The addition of TPP had a defined effect on the color values of the RTC-GF snack (Figure 2). The a* values, which depict the redness of the product, increase significantly ($p \leq 0.05$) with the gradual addition of TP due to the presence of lycopene in it. A higher a* value hinders the acceptability of a sample by consumers [39,40]. Hue angle is used for perception of color while chroma indicates the degree of departure of a color from a grey of the same lightness [25]. The increase in L* values with frying may be attributed to the darkening resulting from Maillard's reaction products [41].

The frying time decreased with the increase in the TPP levels in the snack (Figure 3a). This might be attributed to the fact that the crust achieved a brown color faster due to the higher lycopene content, which in turn is due to an increased percentage of TPP, which might affect one's perception of the quick cooking time, due to the darkening of the crust. A similar trend was also observed for the cooking loss per cent and oil up-take per cent of the snack (Figure 3b). This could be due to the increased moisture binding capacity of TPP, attributed to its fiber content, as evident by the highest cooking loss in T1 with no TPP. Oil uptake by a fried food is primarily due to the formation of pores by evaporation of water from the food surface [42]. The uptake of absorbed oil in food can range from 4 to 14% of the total weight, depending upon the food and type of frying medium, as reported by Andrikopoulos et al. [43] and the results are in conformity with this observation. A number of factors, like the time in and temperature of the oil, type of oil, and the shape and surface of the food and coatings, affect the oil uptake in fried foods [44]. Surface starch gelatinization due to the added gelatinized finger millet paste might have formed a layer that protects the food from oil absorption, as was reported by Califano and Calvelo [45]. Low oil absorption has also been reported by Kim et al. [46] by increasing the addition of preharvest-dropped apple pomace in instant fried noodles. Oil uptake while frying the snack was observed to be less compared to other fried products. This may be due to the reason that since the snack has been formulated with raw materials which have already undergone a preliminary cooking procedure, the chosen frying temperatures were high, both for par-frying as well as finish-frying. Moyano and Pedreschi [47] and Rojas-Gonzalez et al. [48] have argued that lower frying temperatures result in longer frying times and higher oil uptake. The acceptability of the ready-to-cook snack is attributable also to the crispness of the crust that developed due to deep frying, which is a factor of quality and freshness [49]. The increase in hardness may be attributed to the increase in fiber content of the product as well as the decrease in oil content of the fried snack as the level of TPP supplementation increases.

The lower scores for appearance are probably due to the dark color of the crust, which in turn is due to the lycopene content and dark color of FMF. The texture scores also showed a decrease after 15% supplementation with TPP, which might be attributed to the increased fiber content as well as less oil absorption by the snack. The snacks with 10% TP supplementation showed maximum overall acceptability, due to having highest scores for appearance, taste, and texture; the taste parameter had decreased scoring for supplementation beyond 10% due to the increased sourness of the product because of the tomato pomace. Based on these results, the RTC-GF snack with 10% TPP supplementation (T3) had the highest overall acceptability, and was therefore taken up for further storage studies.

FTIR spectroscopy helps to identify the presence or absence of specific functional groups as well as to support the results of chemical analysis [50]. The selected RTC-GF snack (T3) was subjected to FTIR spectroscopy (Figure 5a) for composition determination. The presence of a dominant peak at 2925 cm^{-1} confirms the presence of carbohydrates, being due to aliphatic C-H stretches [51], while the presence of phenolic compounds is confirmed by dominant peaks at 1376.6 cm^{-1} and 1378.5 cm^{-1} which are due to the presence of CH_3 stretch. Similarly, work by Jebitta et al. [52] had a peak at 2931 cm^{-1},

which they reasoned was associated with asymmetric and symmetric stretching modes of alkane C–H. The peak at 1261.1 cm^{-1} and 1241.4 cm^{-1} denotes an asymmetrical C-O-C stretch asserting the presence of phenolic compounds. The absorption bands at 1013.5 cm^{-1} and 1011.3 cm^{-1} are due to C-C and C-O stretching in addition C-O-H bending which are attributed to the structural changes in starch [53]. These bands arise mainly from carbohydrates of cellulosic origin [54]. The peak at 1745.2 cm^{-1} is due to C-O (esters) which indicates lipid characteristics [52]. The absorption bands in the range of 3290 cm^{-1} to 3373 cm^{-1} indicate the presence of hydroxyl groups and denote the OH bond stretch [55] which shows a decrease in percent transmittance in the finished product because of a loss of moisture in the sample product due to the extended frying time and high temperature. Similar data were reported by Gowthamraj et al. [56] and Gull et al. [57]. The presence of an absorption band at 1376–1378 cm^{-1} (C-CH_3 stretching) due to the CH bending vibration indicates the presence of cellulose and hemicellulose chemical structures which are the established components of tomato pomace [58]. Some stretching vibrations at 2854 cm^{-1} and 1745 cm^{-1} might be due to presence of non-starch constituents such as protein and fat [59]. The presence of phenolic compound peaks in the finished product confirms the positive contribution towards antioxidant potential of the final product. Most of the functional groups are retained in the RTC-GF (T3) product, as confirmed from the FTIR spectra of the finished product.

The complete nutritional profile of the RTC-GF snack (T3) and the control snack (T1) is enlisted under Table 3. Most of the vegetarian ready-to-cook frozen snacks available in the market have a protein content in the range of 2 to 3% whereas the RTC-GF snack (T3) has a protein content which is more than double this (6.9%) along with an adequate amount of fiber. As opposed to T1 having no TPP, the RTC-GF snack (T3) delivers a substantial amount of lycopene, which has 10 times the singlet-oxygen-quenching ability as that of α-tocopherol [60]. The processing temperature enhances the absorption of lycopene by altering the trans isomers to cis form [61], which is further enhanced by the addition of oil in the product, since lycopene is fat soluble. The enrichment with TPP in T3 resulted in a higher TPC and TFC of the snack as also reflected in significantly higher antioxidant activity (as DPPH, FRAP, ABTS and MCA). Similar results are reported by Isik and Topkaya, who also observed increased TPC and antioxidant activity in supplemented crackers in their work on tomato pomace supplementation [62]. Dewanto et al. [63] inferred from their studies that thermal processing enhanced the nutritional value of tomatoes and produced no significant changes in the TPC and TFC of tomatoes which helps in enhancing the antioxidant potential as well. The T3 sample also delivers good amounts of minerals, especially calcium, phosphorus, and potassium. Positive calcium content maintains healthy bones [64] while potassium prevents the onset of diabetes, renal, and cardiovascular diseases [65]. 'Western' diets have ω6/ω3 fatty acids in a ratio of up to 20:1, whereas this ratio should be low as this helps in the management of obesity [66]. The RTC-GF snack (T3) has a ratio of 7.1:1, which is quite reasonable and low, as a high ratio of ω6/ω3 is known to be a risk factor in cancers and coronary heart disease [67]. The essential amino acid composition profile of T3 shows that this RTC product is a source of good quality protein as it has valine, lysine, methionine, threonine, and tryptophan in good amounts, as recommended by the WHO [68]. Overall, it also provides sufficient energy (248.2 kcals) and hence good satiation level; thus, the RTC-GF snack (T3), besides being high on energy, also provides good nutritional value.

Lipid oxidation is often the determining factor during shelf studies of foods, since it is the cause of adverse changes in flavor and nutritive value, and has health implications as well. The peroxide value as well as the free fatty acid values of the RTC-GF snack (T3) show a very slight increase during the storage period but the values are well within the acceptable range for both the packaging materials (Figure 6a). Free fatty acids are the result of hydrolytic rather than oxidative rancidity and are used as an indicator of the storage stability of fried foods. A peroxide value of 2.0 meqO_2/kg of fat is normally considered to be low and fats are free of oxidative flavor at this point [69].

The sensory evaluation of the RTC-GF snack during the storage period shows little decrease in the overall acceptability scores of the product. During par frying, the amylose and amylopectin present in the raw material form a gel by losing their crystalline structure, which when cooled at low temperature undergoes retrogradation [70]. During the finish frying of the ready-to-cook frozen snack the retrogradation is reversed and the snack regains its original crispy nature, and this is corroborated by the good overall acceptability scores obtained by the snack which show a non-significant decrease in the values (Figure 6b). The overall acceptability of the product stored in HDPE pouches had higher scores. Hence, it is assumed that the product will show good acceptance beyond the storage study period as well, but further studies are needed to corroborate this.

5. Conclusions

Ready-to-cook frozen snacks are very popular in the market but have limited availability and choice under the gluten-free range. The developed RTC-GF product shows a very high index of acceptability with good storage stability and a very rounded nutritional profile that can very well cater to all sections of society, but specifically to gluten-sensitive people. Besides this, it is made by utilizing a byproduct of the processing industry and hence can help in reducing environmental pollution and attaining sustainability. The product with TPP at 10% level helped in lowering the oil uptake and enhancing the fiber, lycopene content, mineral, and antioxidant activity. Therefore, the utilization of tomato pomace powder in the development of products should be taken up for delivering foods with enhanced nutritional content. Further studies can be undertaken on making suitable interventions to reduce the acidity of the tomato pomace and thus enable its increased addition in food products without adversely affecting the sensorial characteristics.

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