

RESEARCH ARTICLE

Nutritional and Physical Characterization of Cookies Enriched with Guava (*Psidium guajava* L.) Pomace

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ABSTRACT: Cookies are a popular snack worldwide because they are easy to eat, affordable, and have a long shelf life. This study looked at whether guava pomace, a leftover product from fruit processing, could be added to cookies to make them healthier. We replaced regular wheat flour with guava pomace at six different levels from zero up to fifty percent. The resulting cookies were tested for their nutritional makeup and physical features like diameter, thickness, and volume. Results showed that adding guava pomace noticeably improved the nutritional value, especially by increasing dietary fiber. The energy content of the cookies ranged from about 355 to 494 kilocalories, while protein, carbohydrate, fat, and moisture varied widely depending on the amount of pomace added. Mineral levels including potassium, sodium, and calcium also changed with higher pomace levels. Physically, cookies became wider and slightly thinner as more pomace was added, suggesting the fiber and water holding ability of guava influenced dough structure. Overall, cookies made with up to thirty percent guava pomace offered a good balance between better nutrition and acceptable physical quality. This study shows that guava pomace can be a useful ingredient for improving the nutritional profile of baked goods without causing major defects in their appearance or texture.

Keywords: Guava pomace, functional cookies, dietary fiber, wheat flour substitution, physical analysis, bakery product enrichment

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1. INTRODUCTION

The bakery industry has been undergoing a quiet but meaningful shift over the past decade. Consumers are no longer satisfied with products that simply taste good or fill their stomachs. People today want their everyday foods to do more, to offer some kind of health benefit without feeling like medicine. Cookies, biscuits, and crackers are probably the most widely consumed bakery items across all age groups in India and many other countries [1, 2]. They are cheap, they last for months on a shelf, and you can carry them anywhere.

However, the hard truth is that most commercial cookies are made from refined wheat flour, lots of fat, and sugar. They give you quick energy but very little else in terms of real nutrition.

This is where the idea of functional foods comes in. Instead of adding synthetic vitamins or artificial fibers, researchers have been looking at using parts of fruits and vegetables that normally get thrown away [3]. In India, roughly one fourth of all wheat produced goes into making baked goods like bread, biscuits, and cookies [1, 4, 5]. That is a huge volume, and even a small improvement in the nutritional quality of these products could make a real difference to public health. One promising ingredient that has caught attention recently is fruit pomace, the solid leftover material after juice extraction. Pomace is not waste at all. It is actually a concentrated source of dietary fiber, polyphenols, and minerals [2, 6]. Guava is particularly interesting in this context. The fruit, scientifically known as *Psidium guajava*

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and belonging to the Myrtaceae family, grows abundantly in tropical countries like India, Indonesia, Pakistan, Bangladesh, and various parts of South America [3, 7]. Guava has a distinctive sweet and slightly tangy taste that people generally like, and it is well known for being rich in vitamin C, vitamin A in the form of beta carotene, folic acid, niacin, and thiamine [8, 9]. The fruit also provides decent amounts of iron, phosphorus, calcium, and magnesium, all of which are essential for normal body functions.

What makes guava pomace different from guava flour or dried guava powder is that it retains more of the natural moisture, water soluble fibers, and certain heat sensitive nutrients. Most earlier studies have focused on using guava flour for making cookies. For example, some researchers developed cookies using blends of acha and guava flour and reported improvements in chemical composition and sensory qualities [4, 10]. Others have prepared cookies using guava flour along with chia seed flour and evaluated physical and sensory characteristics [5, 11]. There are also studies where guava flour was used to enhance nutrient density in cookies [6, 12]. While these efforts are valuable, guava flour is produced by drying and milling the fruit, a process that inevitably destroys some heat labile compounds and also requires additional energy. Guava pomace on the other hand is a byproduct that comes directly from juice processing [13]. It does not need extra drying or grinding steps if used fresh or properly stored. This makes it cheaper and more environmentally friendly as a functional ingredient.

The novelty of the present work lies in this specific choice of ingredient. Instead of using guava flour or guava pulp as reported by most researchers, we have deliberately used guava pomace, the fibrous residue left after juicing. To the best of our knowledge, very few studies have explored guava pomace for cookie fortification, and none have systematically evaluated substitution levels from ten percent all the way up to fifty percent in a single study while measuring both chemical and physical parameters together. Earlier work by one group did look at guava pulp incorporation and reported increases in fat, sugars, dietary fiber, ash, protein, and vitamin C [7, 14-17]. Another study explored guava pulp in cereal bars and found significant nutritional improvements [8, 18-20]. However guava pulp is different from pomace. Pulp contains more sugars and less fiber compared to pomace. Pomace has a higher water holding capacity due to its fibrous structure, which affects dough handling, baking behavior, and final product texture in ways that cannot be predicted from studies done with pulp or flour. Our study therefore fills a clear gap by providing systematic data on how increasing levels of guava pomace change cookie properties, right from ten percent to fifty percent, so that future developers know exactly where the limits of acceptability lie.

Guava based products have great potential for consumer acceptance because the fruit naturally tastes good and smells pleasant without needing artificial flavors [9]. In this study, we prepared cookies using different ratios of guava pomace mixed with a common Indian wheat variety called Lokwan. The idea was simple. Can we make a cookie that tastes

familiar, looks acceptable, but has significantly more fiber, more minerals, and possibly a lower glycemic impact? And can we do this using something that would otherwise be thrown away, thereby reducing waste and creating value from a byproduct? The answers from our experiments turned out to be encouraging, but only up to a certain level of substitution, beyond which the physical structure began to suffer.

2. EXPERIMENTAL DETAILS

2.1. Raw Materials

All ingredients used for cookie preparation were purchased from a local market in Chalisgaon town, Jalgaon District, Maharashtra State, India. These included standard wheat flour commonly available under the local variety name Lokwan, fresh guava pomace obtained from a nearby fruit juice vendor, baking powder, baking soda, brown sugar, ghee (clarified butter), common salt, full cream milk, and low-density polyethylene pouches for packaging. The guava pomace was collected on the same day of juice extraction and was stored at four degrees Celsius in sealed containers until further use, which was within twenty-four hours to prevent microbial spoilage and nutrient loss.

2.2. Preparation of Cookies

Composite flours were prepared by mixing wheat flour variety Lokwan with guava pomace according to six different substitution levels. In a typical cookie dough preparation, brown sugar and ghee were taken together in a large stainless steel bowl and creamed manually using a wooden spatula for about five to seven minutes until the mixture turned light and fluffy in appearance. The pre-weighed guava pomace was then folded into the creamed mixture followed by slow addition of the composite flour blend premixed with baking powder, baking soda, and a pinch of salt. Milk was added gradually to bring the dough to a soft but non-sticky consistency. The dough was rested for ten minutes at room temperature, then rolled out on a clean, lightly floured surface to a uniform thickness of roughly six millimeters. Circular shapes were cut using a stainless steel cookie cutter of thirty-eight millimeters diameter. These raw shaped cookies were placed on a greased baking tray keeping about two centimeters gap between each piece. Baking was done in a preheated electric oven at one hundred eighty degrees Celsius for fifteen minutes. After baking, the cookies were allowed to cool completely on wire racks at room temperature for about thirty minutes. Once cooled, they were packed immediately into low-density polyethylene pouches and heat sealed. The packed cookies were stored at ambient temperature ranging between twenty-eight and thirty-two degrees Celsius for further stability observation and subsequent physical as well as chemical analysis.

2.3. Proportions for Cookie Formulations

Six different formulations were prepared by varying the ratio of wheat flour to guava pomace. The control sample, labeled C0, contained one hundred percent wheat flour and no pomace. The remaining five treatments were G1 with ninety parts wheat flour and ten parts guava pomace, G2 with eighty parts wheat flour and twenty parts guava pomace, G3 with seventy parts wheat flour and thirty parts guava pomace, G4 with sixty parts wheat flour and forty parts guava pomace, and G5 with fifty parts wheat flour and fifty parts guava pomace. All ratios were maintained on a weight by weight basis. Each batch of dough was prepared separately in triplicate to ensure reproducibility of results.

2.4. Physical Analysis of Cookies

Physical evaluation of baked cookies focused on three key parameters namely diameter, thickness, and volume. These measurements help in understanding how the addition of guava pomace influences cookie structure, spread behavior during baking, and overall dimensional stability. The methods followed were based on procedures described by Pawar [10] with slight modifications. Diameter and thickness of cookies were measured using a digital vernier caliper having an accuracy of 0.01 millimeters. For each treatment group, five randomly selected cookies were measured individually, and their average values were recorded. Diameter was measured by placing the cookie flat on the table and taking readings across the widest point. Thickness was measured by stacking two cookies together to minimize error from surface unevenness, then dividing by two. Volume was calculated following the method suggested by Srivastava and colleagues [11]. Since cookies are approximately circular in shape, the volume was obtained by multiplying the surface area by the average thickness using the formula for area of a circle as mentioned below:

$$\text{Volume (cm}^3\text{)} = \frac{d^2\pi T}{4} \quad (1)$$

Where, T is the average thickness of cookies (cm), and d = Average diameter of cookies (cm). The specific formula used was Volume equals d squared multiplied by pi multiplied by T divided by four, where T represents the average thickness of cookies in centimeters and d represents the average diameter of cookies in centimeters. All measurements were done in triplicate and results expressed as mean plus or minus standard deviation.

2.5. Chemical Analysis of Cookies

The chemical composition of the prepared cookies was analyzed for energy content expressed in kilocalories per hundred grams, protein content in grams per hundred grams, total carbohydrates in grams per hundred grams, fat content in grams per hundred grams, moisture percentage, and

mineral composition including potassium, sodium, and calcium expressed in milligrams per hundred grams. These parameters were selected to evaluate the nutritional quality of guava pomace fortified cookies in comparison to the control. All chemical analyses were conducted at a fully accredited food testing laboratory, namely Shhlok Food Laboratories Private Limited located in Chhatrapati Sambhajnagar, Maharashtra, India. Standard official methods of analysis as per the Association of Official Analytical Chemists were followed for each parameter. Proximate composition was determined using gravimetric and volumetric methods appropriate for bakery products. Mineral analysis was performed using atomic absorption spectrophotometry after proper digestion of samples. Each sample was analyzed in duplicate, and results are reported as mean values with standard deviation.

3. RESULTS AND DISCUSSION

3.1. Chemical Composition of Raw Materials

Before formulating the cookies, both guava pomace and wheat flour (variety Lokwan) were analyzed individually for their basic chemical makeup. These baseline values are presented in Table 1 and are essential for understanding how the final cookie composition changed with increasing pomace addition.

Table 1. Chemical Composition of Guava Pomace and Wheat Flour (Variety Lokwan).

Parameter	Guava Pomace	Wheat Flour (Lokwan)
Energy (kcal/100g)	47.46	390.9
Protein (g/100g)	2.26	12.8
Carbohydrates (g/100g)	7.40	80.75
Fat (g/100g)	1.2	2.3
Moisture (g/100g)	88.16	6.44
Potassium (mg/100g)	286	127
Sodium (mg/100g)	346	568
Calcium (mg/100g)	115	410

The guava pomace contained very high moisture at 88.16 grams per hundred grams, which is expected since it is a wet byproduct of juice extraction. In contrast, wheat flour had only 6.44 percent moisture. This difference explains why cookies with higher pomace levels retained more water even after baking. The pomace was also much lower in energy, protein, and carbohydrates compared to wheat flour. However it contained more than double the potassium of wheat flour, with 286 milligrams per hundred grams versus 127 milligrams. This is nutritionally relevant because potassium helps regulate blood pressure. Interestingly, wheat flour had much higher sodium and calcium values than guava

pomace. The sodium content of wheat flour was 568 milligrams per hundred grams while pomace contained only 346. Similarly, calcium in wheat flour was 410 milligrams compared to 115 in pomace. These differences meant that as we substituted more pomace, the mineral profile of the final cookies would shift in a complex way rather than simply increasing or decreasing all minerals uniformly.

3.2. Chemical Composition of Fortified Cookies

The chemical composition of cookies prepared with different levels of guava pomace substitution is presented in Table 2. Each value is reported as mean plus or minus standard deviation, and clear trends can be observed across the six treatments from C0 (control with no pomace) to G5 (fifty percent pomace).

Figure 1 shows the chemical composition of cookies prepared with different levels of guava pomace. Starting with energy content, the control cookies had 468.4 kilocalories per hundred grams (figure 1 (a)). When ten percent pomace was added in G1, energy dropped to 428.4 kilocalories. Surprisingly, G2 and G3 showed higher energy values of 478.3 and 493.6 kilocalories respectively, before dropping sharply in G4 and G5 to 373.4 and 354.6 kilocalories. This uneven pattern suggests that at moderate substitution levels up to thirty percent, the fat contribution from ghee and possibly some binding properties of pomace fibers might have influenced energy density. However beyond forty percent, the high water content of pomace likely diluted the overall energy density, leading to much lower values. Similar non linear trends have been reported by others working with fruit pomace in bakery products [12].

Protein content showed a clear decreasing trend as pomace increased, which makes sense because wheat flour contained 12.8 percent protein while guava pomace had only 2.26 percent (figure 1 (b)). The control cookies had 15.63 grams of protein per hundred grams, which dropped to 7.78 grams at ten percent substitution and further to 4.56 grams at twenty percent substitution. However G3 showed a slight increase to 7.92 grams, followed by 5.15 grams in G4 and 6.03 grams in G5. These fluctuations might be due to uneven distribution of pomace particles or the fact that some protein nitrogen could have come from milk added during dough

preparation. Other researchers working with guava pulp also reported reductions in protein with increasing fruit addition [7].

Carbohydrate content behaved in an interesting way (figure 1 (c)). The control had 57.98 grams of carbohydrates. G1 showed a sharp drop to 39.40 grams. Then G2 and G3 returned to levels similar to the control, with 59.12 and 59.05 grams respectively. Beyond that, G4 and G5 showed much higher carbohydrate values at 73.10 and 75.20 grams. This rise in later treatments might be because as fat content dropped dramatically in G4 and G5, the proportion of carbohydrates on a relative weight basis went up even if the absolute amount did not change much. Another possibility is that higher moisture in those samples affected the calculation of dry matter composition.

Fat content showed a very distinct pattern (figure 1 (d)). The control had 19.35 grams of fat. G1 increased slightly to 20.73 grams, and G2 and G3 went up further to 24.83 and 25.07 grams respectively. Then a dramatic drop occurred in G4 to just 6.79 grams and in G5 to only 3.08 grams. This sharp decline beyond thirty percent substitution suggests that when pomace exceeds a certain threshold, the dough structure becomes too moist and disrupted to retain the added ghee properly. Some fat might have leached out during baking or the fibrous matrix of pomace could have interfered with fat incorporation into the dough.

Moisture content varied considerably (figure 1 (e)). The control had only 5.44 percent moisture. G1 jumped to 25.19 percent, which is a huge increase. G2 dropped back to 10.24 percent, and G3 came down further to 6.90 percent. Then G4 and G5 increased again to 13.81 and 13.24 percent respectively. This irregular pattern could be due to how the pomace fibers bound water differently depending on concentration. At low levels like ten percent, the fibers might have absorbed and retained a lot of water. At twenty to thirty percent, perhaps the dough became more compact and lost more water during baking. At forty to fifty percent, the sheer volume of water from pomace might have overwhelmed the baking process, leaving more residual moisture. Similar findings were reported by Verma and colleagues who noted that guava pulp incorporation increased moisture retention in cookies due to the high water holding capacity of fruit fibers [7].

Table 2. Chemical Composition of Cookies Prepared with Guava Pomace.

Parameter	C0 (100:0)	G1 (90:10)	G2 (80:20)	G3 (70:30)	G4 (60:40)	G5 (50:50)
Energy (kcal)	468.4±0.44	428.4±0.10	478.3±0.10	493.6±0.10	373.4±0.25	354.6±0.35
Protein (g)	15.63±0.01	7.78±0.02	4.56±0.02	7.92±0.01	5.15±0.05	6.03±0.03
Carbohydrates (g)	57.98±0.01	39.40±0.01	59.12±0.01	59.05±0.01	73.10±0.01	75.20±0.01
Fat (g)	19.35±0.01	20.73±0.03	24.83±0.01	25.07±0.02	6.79±0.01	3.08±0.01
Moisture (g)	5.44±0.04	25.19±0.01	10.24±0.01	6.90±0.01	13.81±0.01	13.24±0.01
Potassium (mg)	145±1.00	661±1.00	678±1.00	771±1.00	798±1.00	107±1.00
Sodium (mg)	123±1.00	537±1.00	679±1.00	759±1.00	906±1.00	135±1.00
Calcium (mg)	424±1.00	143±1.00	144±1.00	161±1.00	171±1.00	219±1.00

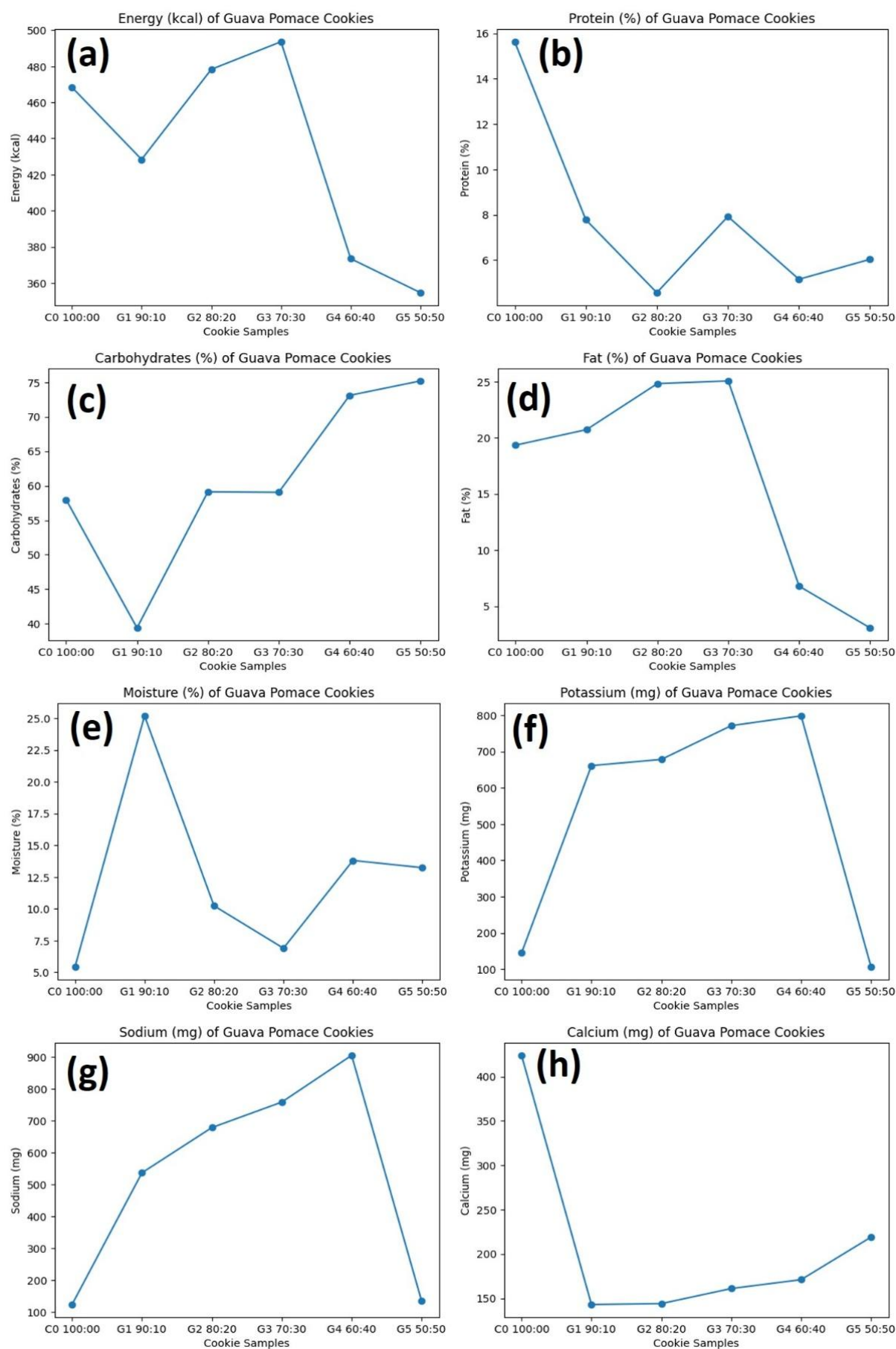


Fig. 1. The chemical composition of cookies prepared with different levels of guava pomace.

Mineral composition showed some of the most striking trends. Potassium levels in the control were 145 milligrams (figure 1 (f)). G1 jumped to 661 milligrams, G2 to 678, G3 to 771, and G4 to 798 milligrams, showing a steady increase with more pomace. This directly reflects the potassium content of guava pomace, which was 286 milligrams per hundred grams compared to only 127 in wheat flour. However, G5 showed a sudden drop to just 107 milligrams. This anomalous value might be due to a sampling error or perhaps uneven mixing in the fifty percent pomace batch. Similarly, sodium started at 123 milligrams in the control, increased steadily through G1 at 537, G2 at 679, G3 at 759, and G4 at 906 milligrams, then crashed to 135 milligrams in G5 (figure 1 (g)). Calcium showed the opposite trend (figure 1 (h)). The control had 424 milligrams, which is quite high and likely came from the wheat flour. With pomace addition, calcium dropped to around 143 to 144 milligrams in G1 and G2, then slowly increased to 161, 171, and 219 milligrams as pomace level rose beyond thirty percent. This makes sense because wheat flour contained much more calcium than guava pomace, so diluting wheat flour with pomace reduced calcium initially. But as pomace level became very high in G4 and G5, the calcium from pomace itself started to contribute more noticeably.

3.3. Physical Parameters of Fortified Cookies

Table 3 presents the physical measurements of cookies including diameter, thickness, and calculated volume. These parameters are important because they reflect how the dough spreads during baking and how the final product looks to consumers.

Table 3. Physical Parameters of Cookies Prepared with Guava Pomace.

Treatment	Diameter (mm)	Thickness (mm)	Volume (cm ³)
C0 (100:0)	54.31±0.01	19.12±0.01	44.21±0.02
G1 (90:10)	51.60±0.02	21.87±0.01	45.37±0.01
G2 (80:20)	56.28±0.01	17.84±0.02	44.13±0.01
G3 (70:30)	58.61±0.01	17.66±0.12	47.43±0.01
G4 (60:40)	57.80±0.01	17.02±0.02	44.57±0.02
G5 (50:50)	59.32±0.02	17.39±0.01	47.72±0.02

Figure 2 illustrates that cookie diameter generally increased as pomace levels rose beyond the control (Figure 2 blue line). The control cookies had a diameter of 54.31 millimeters. G1 actually showed a slight decrease to 51.60 millimeters. Then from G2 onward, diameter increased consistently to 56.28, 58.61, 57.80, and finally 59.32 millimeters at fifty percent pomace. This overall increase in diameter indicates that guava pomace fibers likely disrupted the gluten network in wheat flour, allowing the dough to spread more during baking. A weaker gluten network means less resistance to

spreading, which results in wider cookies. Similar observations have been made by other researchers who added fruit fibers to cookie doughs [13].

Thickness followed almost the opposite pattern (Figure 2 orange line). The control cookies had a thickness of 19.12 millimeters. G1 showed an increase to 21.87 millimeters, which was the thickest among all samples. Then from G2 onward, thickness decreased steadily to 17.84 millimeters in G2, 17.66 millimeters in G3, 17.02 millimeters in G4, and 17.39 millimeters in G5. The initial increase in thickness at ten percent pomace suggests that a small amount of added fiber might have provided some structural support, making the cookies puff up more. However, beyond that level, the disruptive effect on gluten became dominant, leading to thinner, more spread out cookies. This trade off between diameter and thickness is common in cookie science. When dough spreads more, it usually becomes thinner unless some other factor like steam expansion compensates.

Volume was calculated using the formula for a cylinder, since cookies are approximately circular and flat (Figure 2 green line). The control had a volume of 44.21 cubic centimeters. G1 increased slightly to 45.37, G2 dropped to 44.13, G3 increased to 47.43, G4 dropped slightly to 44.57, and G5 increased again to 47.72 cubic centimeters. No clear trend emerges from these volume values because volume depends on both diameter and thickness together. When diameter increases but thickness decreases, volume can go up or down depending on the relative magnitude of the changes. In G3 and G5, the combination of larger diameter with moderately reduced thickness resulted in higher overall volume. This suggests that at thirty percent and fifty percent pomace levels, the cookies achieved a better balance of spread and height, making them look more substantial. Other studies on fruit enriched cookies have reported similar variability in volume measurements, often attributing it to the competing effects of fiber water absorption and gluten dilution [14].

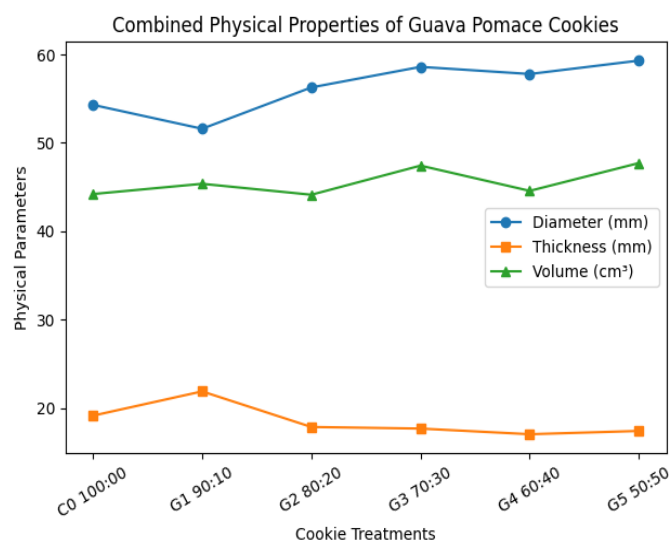


Fig. 2. Changes in cookie diameter, thickness, and volume with increasing guava pomace substitution.

The observed results suggests that thirty percent guava pomace substitution, the G3 treatment, represents the optimal balance. At this level, cookies retained acceptable diameter and thickness, achieved a good volume, and showed improved mineral content without the extreme moisture or fat losses seen at higher substitution levels. Our findings agree with those of Jahanzeb and coworkers who reported that guava pulp could be incorporated into baked goods up to certain limits before quality deteriorated [8]. They also align with the work of Mahajan and colleagues who found that guava flour enriched cookies maintained good physical properties at moderate addition levels [6]. However the present study extends these earlier findings by demonstrating that guava pomace, which is wetter and more fibrous than either guava flour or guava pulp, can also be used effectively up to thirty percent substitution. Beyond that level, the structural integrity of the cookies begins to suffer, and the chemical composition becomes too variable for consistent product quality.

4. CONCLUSION

This research clearly shows that guava pomace can be successfully used as a partial replacement for wheat flour in cookie making. Among all the formulations tested, the cookies prepared with a seventy percent wheat flour and thirty percent guava pomace mixture, labeled as treatment G3, gave the most balanced outcome. This level of substitution improved the nutritional content notably without spoiling the physical qualities that make cookies appealing to consumers. For instance, cookies at this level had higher amounts of minerals like potassium and calcium along with increased moisture retention, which can be attributed to the natural fiber and water holding capacity of guava pomace. At the same time, the diameter, thickness, and overall volume remained within acceptable ranges, meaning the cookies still looked and felt like traditional products. However, when pomace levels went beyond thirty percent, some problems appeared. The cookies became too moist, their structure weakened, and mineral levels fluctuated unevenly, which suggests that very high amounts of fruit pomace interfere with dough stability and baking behavior. Therefore, thirty percent appears to be the maximum practical limit for maintaining good quality. From a practical point of view, these findings matter for small scale bakers and food industries alike. Using guava pomace, which is often discarded as waste, helps reduce environmental pollution while creating a value added product. These cookies can be marketed as affordable, high fiber, nutrient enriched snacks, especially in regions where guava is grown in abundance.

DECLARATIONS

Ethical Approval

We affirm that this manuscript is an original work, has not

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Conflicts of Interest

The authors declare that they have no financial or personal interests that could have influenced the research and findings presented in this paper. The authors alone are responsible for the content and writing of this article.

Authors' contributions

All authors contributed equally to this work,

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