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Use of Mexican Turnips (*Pachyrhizus erosus*) as an Additional Source of Dietary Fiber in Wheat Bread

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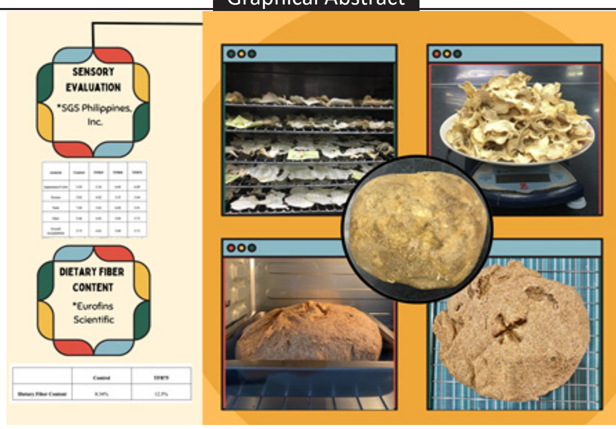
Graphical Abstract



Abstract

This study focused on dietary fiber, a critical element in flour, especially wheat flour, and its potential to enhance bread's dietary fiber content. The feasibility of using turnips, recognized for their rich dietary fiber content, in bread-making was explored. The process involved blanching, drying, and pulverizing raw turnips to form a flour blend. This blend was then compared to standard wheat flour through a comprehensive analysis of bread quality. Sensory evaluation, assessing appearance, texture, taste, and odor, was employed to gauge the acceptability of bread made with the turnip-flour blend. The study aimed to highlight the benefits of diversifying flour sources by incorporating high-fiber ingredients such as turnips and to increase the demand and value of turnips by showcasing their versatility in alternative culinary applications. The sensory analysis indicated that bread made with a 75% turnip flour blend is acceptable. This blend, along with a control sample, was then subjected to the AOAC 991.43 Gravimetric method to measure dietary fiber content. Results showed an increase from 8.34% in the control bread to 12.5% in the turnip flour blend bread. Interestingly, the study found no significant differences in sensory attributes between the control and experimental samples. This suggests that exploring alternative formulations could further enhance the overall quality of bread made with a turnip flour blend. This research, therefore, emphasized the potential for turnips to play a larger role in nutritionally enriching our daily bread.

Keywords: Dietary Fiber; Sensory Analysis; Turnips; Turnip Flour Blended Bread; Wheat Flour

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Introduction

Flour is one of the essential ingredients needed in any baking recipe. It contains proteins that mix with liquids to form gluten, which gives baked foods their structure [1]. However, refined flour retains little to no fiber at all. Furthermore, there are concerns that refined flour consumption increases blood sugar and insulin levels, resulting in metabolic dysfunction.

Dietary fiber regulates the human digestive system as well as stabilizes glucose in our body which is essential for people having diabetes [2]. Lack of dietary fiber could cause obesity, constipation, diabetes, heart disease, bowel cancer, and breast cancer [3]. According to the European Food Safety Authority (EFSA), dietary fiber (DF) is a non-digestible carbohydrate plus lignin [4]. In addition, food containing at least 3 g/100 g or 1.5 g/100 kcal of dietary fiber can be referred to as a “source of fiber”, while food containing at least 6 g/100 g or 3 g/100 kcal of dietary fiber can be referred to as “high in fiber” [5]. Examples of foods that are rich in fiber are turnips, bananas, nuts, broccoli, potatoes, carrots, brown rice, etc. [6-8].

According to Pintado et al. [9], fruits and vegetable by-products (FVB) may be used as an alternative ingredient to produce fiber-enriched flours due to their high nutritional content values and bioactive compounds. In Zlatanovic et al. [10], apple pomace (peel, pulp, stem, and seeds) from the juice industry was utilized as a substitute for wheat flour which was then incorporated into the production of cookies. The result of the study shows that apple pomace flour (APF) possesses a high dietary fiber content (42%) and other health-promoting compounds such as polyphenols and flavonoids. In addition, the cookies mixed with APF resulted in an intensely fruity aroma and a nice crisp texture making them acceptable for consumers. Based on the aforementioned results, APF has shown good results and that they have the potential for flour production.

Turnip (*Pachyrhizus erosus*) is a root vegetable originally from the Fabaceae family which is similar to radish and swedes [11]. Turnips are one of the horticultural crops worldwide because of their nutritional value and they can be used to feed humans and cattle [11] There are different varieties of turnips around the world such as the Scarlet Queen Turnip which has magenta-colored skin, the snowball turnip which is a Japanese heirloom plant, Nozawana, a Japanese turnip that is grown mostly for its excellent, long, dark green leaves, and many more [12,13]. However, in this study, the researchers will only focus on the variety that is found and cropped in the Philippines - Mexican turnips. Mexican turnips, which are locally referred to as Singkamas, Jícama (Spanish), and Yam bean root, belong to one of the species in the genus *Pachyrhizus* [14]. According to a study conducted by Tanaka, H., et.al, Jicama consists of two types of amylose: fructooligosaccharides and inulin, which is one of the main reasons for its high dietary fiber content which can range between 49% to 56% depending on its variety [15].

Due to the excellent nutritional value of Jicama, particularly its fiber content, the study aims to utilize this as an additional source of dietary fiber in the production of bread using fiber-enriched wheat flour.

Methodology

Utilized turnips, with a total weight of 28 kg, for the research methodology were purchased from the market in Biñan City, Laguna. According to the vendors from the market, turnips were supplied to them from Baguio City, Benguet.

Research Paradigm. There were three setups involved in the process of making bread dough. The first formulation was composed of 25% w/w of turnip flour and a cup of wheat flour. Likewise, 50% w/w and 75% w/w of turnip flour were added for the other two formulations.

Preparation of Turnip Flour. For the production of turnip flour, round-shaped turnips were peeled, cut into small pieces, and blanched in hot boiling tap water at 95±5˚C for 2-3 minutes [16-18]. After blanching, the turnips were cooled, weighed, and tested for initial moisture content using a moisture analyzer. Before proceeding with the drying process, six randomly selected slices of turnips were tested for their initial moisture content using a moisture analyzer. Using a food dehydrator, turnips were dried at 85±10˚C for 380 minutes or 6.33 hours [19]. The dry-bulb temperature and wet-bulb temperature were measured using two thermometers, one without wet cotton and one with partially wet cotton at the tip of the thermometer, every 30 minutes.

After dehydrating the samples, the dried turnips were tested again using a moisture analyzer to assess and analyze their final moisture content to ensure the drying process achieved the target final moisture content of 10% or less, such that no microorganisms would grow in the sample. By utilizing a food-grade blender, dried turnips were pulverized into powder/flour [20] and were then sieved using a screen with mesh number 70 (212 microns) to ensure that the turnip flour has no significant variation in its particle sizes [21]. The powdered turnips were then stored in zip-lock bags and refrigerated until use.

Bread Production for Comparison. For bread production, the measurements of each ingredient are shown in Table 1, which is based on the study of Bolarinwa et al. (2019). For the control sample, 100% wheat flour was incorporated into the bread. Subsequently, for the test samples, 1 cup of ordinary wheat flour was added with 25% w/w, 50% w/w, and 75% w/w of turnip powder.

Shown in Table 1 are the required ingredients as well as their corresponding measurements. These were mixed for about 4-5 minutes, and the dough was added by 1/2 cup of wheat flour at a time until the dough began to pull away from the sides of the bowl. The dough was smooth and slightly sticky to the finger but not overly sticky. A separate bowl was greased with cooking oil, and the dough was placed inside. The bowl was covered with plastic wrap, and the dough was allowed to rise until it doubled in size for about 1.5 hours. While waiting for the dough to rise, the oven was preheated to about 175 degrees Celsius. After the dough has risen, the dough was baked in the oven for about 33 minutes or until the top of the bread was golden brown.

Table 1. Formulation of control and experimental samples

Sample	Wheat flour (g)	Turnip flour (g)	Salt (g)	Yeast (g)	Butter (g)	Sugar (g)	Water (mL)
Control	400	0	4	8	40	48	240
TFB25	300	100	4	8	40	48	240
TFB50	200	200	4	8	40	48	240
TFB75	100	300	4	8	40	48	240

TFB25: bread with 25% turnip flour blend, TFB50: bread with 50% turnip flour blend, TFB75: bread with 75% turnip flour blend.

Sensory Evaluation. The sensory analysis was conducted at SGS Philippines, Inc, located in Makati, Metro Manila. A 9-point Hedonic Scale was used to determine the Overall Acceptability per attribute of the four (4) treatments of the Bread Sample. Eleven evaluators were requested to assess the samples, and the samples were coded and distributed randomly. Each serving of the sample was accompanied by a cracker and a glass of water to ensure that the taste buds were reset between each tasting. The data collected from the sensory analysis were analyzed statistically to determine any significant differences in the sensory attributes and overall acceptability of the bread samples.

Dietary Fiber Testing. The analysis of the dietary fiber content of the samples was done in the testing laboratory center of Eurofins in Vietnam. The control and the preferred experimental sample (75% turnip-flour blend) underwent AOAC 991.43 gravimetry method to determine its dietary fiber content.

Statistical analysis. The analysis of all samples was conducted, and their results were averaged. To identify significant differences between the mean values, the analysis of variance (ANOVA) was employed, and Duncan's multiple range test (DMRT) was performed at a significance threshold of $p<0.05$ utilizing Microsoft Excel 2016 version [22].

Results and Discussion

The raw turnips sample had a mass of 28 kg. After being processed and dried, they weigh significantly less, with the dried turnips weighing only 1.181 kg. The turnip flour, further processed from the dried turnips, weighs even less, at 1.080 kg. This drastic reduction in weight from the raw turnips to the turnip flour is attributed to the high water content of turnips. The fresh turnips are composed of 84% water as measured from the moisture analyzer, so when they are dried and then processed into flour, the bulk of the original weight is lost. This is consistent with the concept of dehydration in food processing, where water is purposefully removed to prolong the shelf life of the food and make it lighter and easier to store and transport [23].

The results indicated that only about 4.18% of the total weight of the raw turnips was converted into turnip flour. This means that for every 100 kg of raw turnips processed, only about 4.18 kg of turnip flour is produced. Given the high percentage of water in turnips (84%), it was calculated that around 84% of the total weight of the raw turnips was water, which was removed during the dehydration process.

These results highlight the resource-intensive nature of producing turnip flour. The process requires a significant amount of raw turnips to yield a relatively small amount of flour. It's also important to note that the energy and resources used in the drying and milling processes contribute to the overall cost of producing turnip flour [24]. These results can help businesses, especially in starting a business, estimate the quantity of raw turnips needed to produce a certain amount of turnip flour, which can aid in cost and resource planning. The process can also provide consumers some insights into the cost of turnip flour and why it may be higher than other types of flour.

Sensory Analysis. The services of SGS Philippines, Inc. were enlisted in the conduct of the sensory analysis of the baked bread samples. The primary objective of this evaluation was to ascertain the participants' preferences and perceptions concerning the appearance, texture, taste, and odor of the bread. For this purpose, a 9-point hedonic scale was utilized, with scores ranging from 1 (indicating extreme dislike) to 9 (signifying extreme like). A panel of 11 members evaluated the samples under strictly controlled conditions. The results of the sensory analysis are presented in Table 2. Moreover, a visual representation of these results is available in Figure 1.

Based on the data presented in Table 2, the majority of the scores fell between 5 (Neither like nor dislike) and 6 (Like slightly), with the control sample having achieved the highest score of 7 (Like moderately) for taste. Upon application of Duncan's Multiple Range Test (DMRT), it showed that there are no significant differences ($p<0.05$) in taste between the control and the three test samples. This means that the taste of the bread does not change significantly when up to 75% of the wheat flour is replaced with turnip flour. It suggests that turnip flour can be used as a substantial replacement for wheat flour in bread without negatively impacting the taste. Furthermore, the bread samples exhibited no significant variations ($p<0.05$) in their appearance and color, as all were subjected to the same recipe and baking conditions. TFB75 obtained the highest score for this attribute, obtaining a mean score of 6.09.

Texture showed no significant differences between the samples as well, even with the control sample scoring highest, at 5.82. This suggests that substituting up to 75% of wheat flour with turnip flour in bread does not noticeably change the texture of the bread. Odor also showed no significant differences, with TFB75 having the highest score among the panelists. This implies that replacing up to 75% of wheat flour with turnip flour in bread does not significantly affect the bread's aroma.

Table 2. Overall Acceptability Total Score per Attribute provided by SGS Philippines, Inc.

Analysis	Control	TFB25	TFB50	TFB75
Appearance/Color	5.50 ± 1.21^{a}	5.36 ± 1.43^{a}	6.00 ± 1.26^{a}	6.09 ± 1.38^{a}
Texture	5.82 ± 1.47^{a}	4.82 ± 1.83^{a}	5.55 ± 1.92^{a}	5.64 ± 2.06^{a}
Taste	7.00 ± 1.57^{a}	5.82 ± 2.40^{a}	6.00 ± 2.12^{a}	5.91 ± 2.33^{a}
Odor	5.46 ± 1.33^{a}	4.82 ± 0.69^{a}	5.09 ± 1.04^{a}	5.73 ± 1.10^{a}
Overall Acceptability	5.73 ± 0.90^{a}	4.82 ± 1.78^{a}	5.00 ± 2.14^{a}	5.73 ± 2.10^{a}

TFB25: bread with 25% turnip flour blend, TFB50: bread with 50% turnip flour blend, TFB75: bread with 75% turnip flour blend. Data are average scores ± standard deviation. Values in the same row with different superscripts are statistically significant ($p<0.05$).

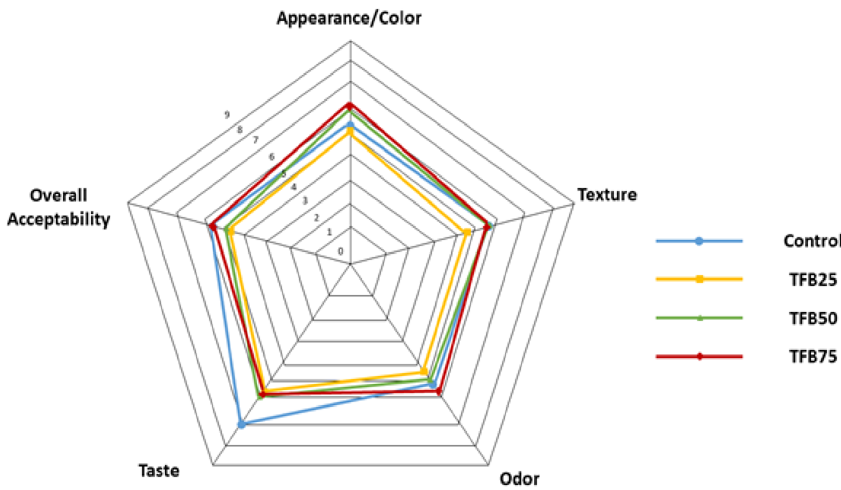

Figure 1. Sensory profile of bread samples.

Overall, TFB75 scored 5.73, making it as acceptable as the control bread. According to ANOVA, there were no significant differences ($p<0.05$) between the samples. In addition, there was also no minimal interaction between the sensory attributes and the samples, suggesting that the sensory attributes of the bread samples largely depend on panelists' preferences and not the nature of the bread samples. Despite no significant difference between the samples, further research is needed to enhance the bread's overall quality and to explore the most effective ways of incorporating turnip flour into bread. The overall acceptability score of 5.73 for the control sample suggests room for improvement in the bread recipe, potentially affecting scores for the experimental samples.

Dietary Fiber Content Analysis. Analysis of dietary fiber content of the bread sample with 75% turnip flour blend and of the control bread sample was performed by Eurofins scientific SE using AOAC 991.43, Gravimetry Method.

The control bread contains 8.34% dietary fiber, while the bread made with a 75% turnip flour blend (TFB75) exhibits an increased dietary fiber content of 12.5%. Thus, the experimental bread enriched with turnip flour has an added dietary fiber content of 4.16%. Serving as a low-carb option to conventional flour like wheat, TFB75 provides a beneficial choice for individuals aiming to reduce their carbohydrate intake while maintaining a fiber-rich diet. This integration significantly elevates the overall nutritional value of the bread.

Considering the results of sensory evaluations, which show no significant differences when using turnip flour, it could be explored as a gluten-free bread ingredient for people with gluten allergy. Turnip flour is gluten-free and can be mixed in specific ratios with other types of flour to retain the desired texture and structure of the bread. Furthermore, turnip flour introduces a unique flavor profile, imparting a distinct taste to the bread. Therefore, given its gluten-free nature, turnip flour holds potential as an alternative bread ingredient for those who are gluten intolerant.

Conclusion

This study aimed to compare the characteristics and quality of bread made with conventional flour and a turnip flour blend. Additionally, it sought to assess the quality and acceptability of bread made using the turnip flour blend and to determine the potential for this blend to increase dietary fiber content in bread as an additional source of fiber to standard flour. The process involved drying and pulverizing turnips, baking bread samples with a turnip flour blend, conducting sensory analysis, and analyzing the dietary fiber content. Findings suggest that none of the alternative formulations significantly deviated from the control in terms of sensory properties, indicating that the addition of turnip flour does not markedly alter these characteristics. It's essential to note that this study primarily evaluated the sensory properties of the bread. Other aspects to consider when incorporating turnip flour into bread formulations might include nutritional value and shelf-life, suggesting the potential for further research in these areas to determine the optimal recipe for bread made with a turnip flour blend. The ANOVA analysis also revealed no significant differences in sensory attributes between the control and experimental samples. Furthermore, it suggests the possibility of increasing the turnip flour ratio in the recipe, as the formulations were not significantly different from the control. In conclusion, it's evident that supplementing a bread recipe with a turnip flour blend can result in an increased dietary fiber content. Specifically, a 75% turnip flour blend led to a dietary fiber increase of 4.16%. This validates the potential of turnip flour as a healthier additional source of fiber in bread-making.

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Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization, R.HI. and E.C.; methodology, P.HM. and R.LM..; data collection, R.HI., P.HM. and R.LM.; analysis and interpretation of data, R.HI., P.HM., and R.LM.; original draft preparation, R.HI., P.HM., and R.LM.; review and editing of the draft, R.HI., P.HM., R.LM., and E.C..

All authors have read and agreed to the final version of the manuscript.

Institutional Review Board Statement

Ethics Review Board permit is not necessary since the evaluation process involving humans was outsourced (SGS Philippines).

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