Research Article

Developing Healthier Biscuit Alternatives: An Analysis of Tapioca, Desiccated Coconut, and Wheat Flour Blends

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ABSTRACT

This study aimed to identify the optimal biscuit formulation using blends of tapioca flour, desiccated coconut flour and wheat flour. Four formulations, denoted as F1, F2, F3, and F4 with varying ratios of wheat flour, tapioca flour, and desiccated coconut flour (30:20:50, 30:30:40, 30:40:30, and 30:50:20 respectively), were produced. Multiple methodologies were employed to study the impact of composite flour on the quality of cookies, including sensory evaluation, proximate analysis, and physical evaluations. After a hedonic test involving 50 panelists, F3 emerged as the superior formulation. Proximate and physical analyses for F3 and the control (100% wheat flour) revealed notable differences. The proximate composition results showcased distinct differences between the best formulation (F3) and the control. F3 exhibited higher values ($p<0.05$) in moisture content (2.33±0.37%), crude fibre (4.05±0.02%), and carbohydrate content (65.04±0.74%) compared to the control. However, both formulations displayed similarities ($p>0.05$) in terms of spread ratio, colour, and pH, despite their differing composition in formulation. Notably, F3 surpassed the control in nutrient composition, especially in moisture, crude fibre, and carbohydrate content. In conclusion, the investigation into these blended flours has demonstrated promising outcomes, emphasising their potential to not just enhance the nutritional quality of biscuits but also elevate consumer contentment.

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1. Introduction

The increasing utilisation of biscuits, shifting from being just consumed as snacks to being incorporated into breakfast meals, has amplified the need for biscuits in the worldwide industry. The Malaysian market is witnessing a surge in convenience foods and ready-to-eat meals, driven by increasingly hectic urban lifestyles. Biscuits, a longstanding convenience food, have become a significant part of this trend. Typically, biscuits are small baked products primarily comprising a wheat base, enriched with fat and sugar, which can vary in ingredients and processing methods to enhance attributes like flavor, texture, and crispness. These snacks boast long shelf life due to low moisture content (1-5%) and a higher energy density from increased fat content compared to other baked goods. However, the term 'biscuit' can carry different meanings globally; for instance, what Americans call 'cookies' might be termed 'biscuits' in the UK, akin to scones (Misra & Tiwari, 2014).

Originally, 'biscuit' stems from the Latin word 'bis coctus' (or 'panis biscotis') and later the French 'bescuit' (or 'bis-qui'), both implying 'twice-cooked bread.' Historically, biscuits served as staple rations for various groups, offering cheap sustenance and extended shelf life. Today, these treats serve not only as snacks but are also transformed into functional foods enriched with dietary supplements. These functional foods positively impact health beyond mere nutrition by enriching or substituting ingredients to fortify biscuits (Manley, 2011; Dhankhar & Tech, 2013). In the realm of biscuits and baked products, composite flours (CFs) play a crucial role by partially or fully substituting conventional wheat flour. CFs, derived from roots, tubers, cereals, and legumes, offer alternatives that eliminate gluten, a common allergen in wheat and related grains. This substitution with CFs not only enhances nutritional value but also aligns with economic benefits by encouraging the use of locally grown crops (Noorfarahzilah *et al.*, 2014; Julianti *et al.*, 2017).

Coconut and cassava emerge as promising ingredients for CFs. Cassava, or tapioca, belonging to the family Euphorbiaceae, serves as a versatile, easily grown tuber with various applications. Tapioca consists entirely of carbohydrates and lacks fat or protein. It does, however, offer some vitamins and minerals, including iron and potassium (Mamat *et al.,* 2020). Similarly, coconut, recognized for its nutritional richness, offers diverse products like coconut oil, milk, and flour. Coconut flour, a by-product of the virgin coconut oil industry, holds high nutritional value, including a rich fibre content and beneficial compounds like lauric acid (Lal *et al.*, 2003; Howeler, 2004; Dhankar & Tech, 2013). However, no studies have explored the exclusive use of tapioca flour and desiccated coconut powder blends in CFs for making biscuits. Consequently, there exists a notable lack of information regarding the attributes of biscuits formulated with desiccated coconut and tapioca CFs. This knowledge gap extends to the optimal flour ratios necessary for creating nutritious, appealing, and marketable biscuit products. Current biscuits available in the market often lack substantial nutritional value due to their predominant use of wheat-based flours. Despite this, biscuits hold significant potential as a vehicle for promoting healthier eating habits. Introducing desiccated coconut and tapioca CFs could potentially address this gap in the market, offering healthier snack alternatives that cater to the needs of individuals such as diabetics and health-conscious consumers seeking convenient yet nutritious food options (Fauad *et al.*, 2020).

This study aims to shed light on the expected outcomes when utilizing desiccated coconut and tapioca flour blends in composite flours, serving as a valuable reference for researchers and innovators seeking to create their own composite flours from these ingredients. Additionally, this research will yield crucial insights into the physicochemical characteristics, flavor profiles, consumer acceptance, and marketability of these composite flours. As consumer awareness of healthier foods grows, this investigation is positioned to demonstrate the potential of desiccated coconut and tapioca composite flours as functional food ingredients. Moreover, biscuits serve as versatile snacks appealing to various age groups and can be customized into diverse flavors while maintaining a longer shelf life compared to other baked goods.

2. Materials and Methods

2.1 Materials

The tapioca flour, desiccated coconut, wheat flour, and additional ingredients for making the biscuits were obtained from local stores in Kota Kinabalu, Sabah, Malaysia. The details outlining the materials and their corresponding brands are presented in Table 1.

2.2 Preparation of composite flour and biscuit formulations

The biscuit recipe was formulated by blending methods from AACC (2000) Method 10-53 for wire-cut cookies, along with recipes from El-Sharnouby *et al.* (2012) and Paucean *et al.* (2016), with some adjustments. Four biscuit formulations were produced and designated as Formulation 1 (F1), Formulation 2 (F2), Formulation 3 (F3), and Formulation 4 (F4). These formulations involved replacing a portion of wheat flour with varying ratios of desiccated coconut flour and tapioca flours. Specifically, the proportions of the flours used in each formulation, in the order of wheat flour, tapioca flour, and desiccated coconut flour, were as follows: 100:0:0 for the Control, 30:20:50 for F1, 30:30:40 for F2, 30:40:30 for F3, and 30:50:20 for F4. The selection of these ratios was made following preliminary research. Table 2 shows formulations used in biscuit making for this study.

Table 1 List of materials needed for both biscuit productions.

Materials	Source/Brand
Tapioca flour	Bataras 1Borneo Kota Kinabalu/ MH Food
Low fat desiccated coconut	Bake With Yen (BWY) Kota Kinabalu/ Rasaku
Margarine	Bataras 1Borneo Kota Kinabalu/ Puteri
Granulated sugar	Bataras 1Borneo Kota Kinabalu/ CSR
Egg	Bataras 1Borneo Kota Kinabalu/ NutriPlus
Ammonium bicarbonate	Bake With Yen (BWY) Kota Kinabalu
Sodium bicarbonate	Bake With Yen (BWY) Kota Kinabalu/ Kings
Vanilla essence	Bake With Yen (BWY) Kota Kinabalu/ Star Brand
Iodized salt	Bataras 1Borneo Kota Kinabalu/ Magic Cook

Table 2 Formulations of biscuit making.

Ingredient	Control (%)	F1 (%)	F2 (%)	F3 (%)	F4 (%)
Wheat flour	100.00	30.00	30.00	30.00	30.00
Tapioca flour	0.00	20.00	30.00	40.00	50.00
Desiccated coconut flour	0.00	50.00	40.00	30.00	20.00
Sugar	20.00	20.00	20.00	20.00	20.00
Margarine	15.00	15.00	15.00	15.00	15.00
Egg	7.50	7.50	7.50	7.50	7.50
Ammonium bicarbonate	0.63	0.63	0.63	0.63	0.63
Sodium bicarbonate	0.63	0.63	0.63	0.63	0.63
Salt	0.25	0.25	0.25	0.25	0.25
Vanilla Essence	1.00	1.00	1.00	1.00	1.00
Water	5.00	5.00	5.00	5.00	5.00

2.3 Biscuit making process

Desiccated coconuts were ground into flour, mixed with tapioca until smooth, and set aside. Dry ingredients such as ammonium bicarbonate, sodium bicarbonate, and salt were combined evenly with the flours.

In a separate bowl, margarine and honey were whipped together before adding egg and vanilla essence, creating a smooth mixture. The dry ingredients were added gradually until a soft dough formed. After chilling for 20 minutes, the dough was rolled to 3.5 mm thickness, cut into 5 cm circles, and baked at 180°C for 15 minutes. Once cooled, the biscuits were stored in zip lock bags for further analysis.

2.4 Sensory evaluation

A total of 50 untrained panelists were recruited from staff and students of Universiti Malaysia Sabah (UMS). The sensory characteristics of the biscuits were evaluated in a standard sensory laboratory at the Faculty of Food Science and Nutrition, UMS, Malaysia, where each panellist was situated in the respective isolated booths under white light. Biscuit samples were labelled with randomized three-digit codes and served at ambient temperatures on plastic plates. Plain water was the palate cleanser of choice for rinsing of mouth in between samples. Panellists were asked to rate given products by characteristics: colour, taste, appearance, texture and overall acceptability using a 9-point hedonic test with scores 9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like nor dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much, and 1 = dislike extremely (Mamat *et al.,* 2023). The evaluation was performed at room temperature (27°C) and under a consistent relative humidity of 80%.

2.5 Proximate composition analysis

The proximate analysis involved a comprehensive examination to ascertain the composition of moisture, ash, crude protein, crude fat, and crude fibre percentages. This analytical procedure was executed in strict accordance with the guidelines stipulated by the Association of Official Analytical Chemists (AOAC, 2000). Additionally, the determination of carbohydrate content was accomplished using the method delineated by Nitisewojo (1995), calculated through the difference approach within the overall composition analysis.

2.6 Physical measurement

Biscuit colour assessment employed the Konica Minolta Chroma Meter CR-400 Colorimeter, presenting outcomes using the CIELAB system. This evaluation captured distinct factors: lightness (L^* = 100 for white, 0 for black), green-red chromaticity (a^* = ranging from -60 for green to +60 for red), and blue-yellow chromaticity (b^* = ranging from -60 for blue to +60 for yellow). Prior to the analysis, the colorimeter underwent calibration using a white tile, as stipulated in the methodology by Ho and Nadratul Wahidah (2016). For pH analysis, the biscuit samples adhered to the AOAC (2000) method. Furthermore, a calibrated texture analyser (Stable Micro System, UK), equipped with a three-point bending kit, was utilized to conduct penetrometry tests on the biscuits, assessing their hardness (Sharoba *et al.*, 2014).

According to the AACC (2000) guidelines, hardness evaluation was performed 24 hours post-baking, gauging the maximum force (N) the biscuits could endure before breaking (Dhankar & Tech, 2013). These tests followed specific parameters: a pre-test speed of 2 mm/s, a test speed of 1 mm/s, a post-test speed of 5 mm/s, and a compression distance of 3 mm for the biscuit samples (Ho & Nadratul Wahidah, 2016). To determine the spread ratio of biscuits, the methods described by Ali and Abol-Ela (2019) were employed. The diameter and thickness of the biscuits were measured using vernier calipers. Five biscuits were aligned edge to edge to measure their combined width, and the average width was calculated by dividing the total by five. Similarly, stacking five biscuits allowed for measuring their combined height, and the average thickness was obtained by dividing this total by five.

2.7 Statistical analysis

The sensory data underwent statistical analysis through IBM Statistical Package for the Social Sciences (SPSS) software version 27.0. Sensory evaluation involved the use of one-way analysis of variance (ANOVA) tests. Meanwhile, proximate and physical analyses were conducted utilizing the independent sample T-test. In all analyses, differences at $p<0.05$ were deemed significant.

3. Results and Discussion

3.1 Sensory evaluation

Figure 1 illustrates the biscuits made from a blend of tapioca, desiccated coconut, and wheat composite flour. The assessment of biscuit properties was conducted using a 9-point hedonic scale, encompassing colour, appearance, taste, texture, and overall acceptability across four distinct formulations. Detailed in Table 3, these results provided a comprehensive view of the evaluated attributes.

Acknowledged as a pivotal quality attribute for consumer acceptance, colour not only stimulates appetite but also profoundly influences perceptions of texture and taste. The ranking order of colour preference among the formulations was F3, F2, F4, and F1, respectively. While statistical analyses unveiled no significant differences ($p>0.05$) between mean values for F2, F3, and F4, all three formulations markedly differed from F1 ($p<0.05$) in terms of colour attributes. Comments in the questionnaire illuminate that F4 could benefit from a darker hue or longer baking duration, whereas F1 received criticism for excessive darkness, possibly due to varied biscuit spread and rise during baking. The variance in spread influenced the baking duration, as biscuits with greater spread tended to cook faster (Panghal *et al.*, 2018). Consequently, F1 turned overcooked, assuming a burnt and lackluster colour.

Figure 1 Biscuits produced from a blend of tapioca and desiccated coconut composite flour.

Table 3 Sensory evaluation results of biscuit.

Formulation[1]	Attribute				
	Colour	**Appearance**	**Taste**	**Texture**	**Overall Acceptability**
F1	5.22±2.14^{a}	5.56±2.17^{a}	4.90±2.26^{a}	5.10±2.08^{a}	5.34±2.20^{a}
F2	6.36±1.83^{b}	6.50±1.75^{b}	6.18±1.73^{b}	6.20±1.71^{b}	6.60±1.65^{b}
F3	6.62±1.47^{b}	6.60±1.60^{b}	7.14±1.49^{c}	6.92±1.48^{bc}	7.32±1.32^{b}
F4	6.22±1.63^{b}	6.54±1.61^{b}	7.26±1.54^{c}	7.18±1.47^{c}	7.30±1.31^{b}

[1]F1, 30:20:50; F2, 30:30:40, F3, 30:40:30 and F4, 30:50:20 where ratios are wheat flour: tapioca flour: desiccated coconut. Mean values with the same superscript letter within the same column were not significantly different ($p>0.05$).

In evaluating appearance, F3 emerged with the highest mean score, followed by F4, F2, and F1. Statistical analysis highlighted no substantial differences ($p>0.05$) among F2, F3, and F4, except for F1 ($p<0.05$). The interrelation between colour and appearance was robust, with appearance encompassing optical properties, physical form, and presentation mode, influencing consumer assessments on multiple fronts, including safety, identification, and satisfaction (Liu *et al.*, 2020). Notably, consumer expectations regarding appearance significantly affect taste perception. F1's evident darkness led to a perceived inferiority, aligning with colour analysis where F1 significantly differed from F2, F3, and F4.

F4 received the highest rating, followed by F3, F2, and F1. Despite F4 achieving higher scores, no significant differences ($p>0.05$) existed between F3 and F4, although both differed significantly from F1 and F2. Feedback from the questionnaire revealed that F1's low rating stemmed from a pronounced burnt taste, evoking bitterness on the palate. The Maillard reaction, which is accountable for the process of caramelization and the development of intricate flavors, led to the formation of undesirable compounds that masked the intended buttery flavor of margarine and the nutty flavor of desiccated coconut. The perception of taste, encompassing sweet, sour, salty, bitter, and umami sensations on the tongue, acts as the ultimate arbiter for consumer acceptance (Melis & Barbarossa, 2017).

F4 scored highest, followed by F3, F2, and F1. Although F3 did not significantly differ ($p>0.05$) from F2 and F4, F2 significantly differed ($p<0.05$) from F4. Conversely, F1, with its lowest texture score, significantly differed from the other formulations, possibly due to excessive drying caused by overbaking, leading to increased brittleness and an inability to achieve the desired melt-in-the-mouth sensation.

For overall acceptance, F3 emerged with the highest mean score, closely followed by F4, with a minor difference of 0.02 in scores. Conversely, F1 consistently scored the lowest, significantly differing from the other formulations, corroborating previous sensory evaluations. In conclusion, F3, with a composition ratio of 30:40:30 for wheat flour, tapioca flour, and desiccated coconut, emerged as the optimal formula. Despite statistical similarity between F3 and F4 across parameters, the choice of F3 prioritized the nutrient richness of coconut over nutrient-poor tapioca flour, aiming to enhance the overall nutrient profile and quality of the biscuit (Sundaresan *et al.,* 2023).

3.2 Proximate analysis

Table 4 depicts the proximate composition of the best formulation (F3) and control biscuits produced using different percentages of tapioca and desiccated coconut flour. The results showed that the moisture content in F3 significantly surpasses that of the control formulation ($p<0.05$), typically falling within 1-5% for extended shelf-life (Misra &Tiwari, 2014). F3's higher moisture, attributed to desiccated coconut's dietary fibre richness (Trinidad *et al.*, 2006), aligns with its elevated crude fibre content (4.05±0.02%) known for moisture retention (Dhankar & Tech, 2013). However, excessive moisture can negatively affect crispness, while levels below 1.4-1.6% may induce biscuit drying or staling due to reduced retrogradation (Goyat *et al.*, 2016). In comparison, the ash content exhibited a similarity between F3 and the control group ($p>0.05$). However, it is possible that the variation seen in F3 could be attributed to differences in wheat cultivars and tapioca root age, which may have an impact on the ash and fibre content (Falade & Akingbala, 2008).

Despite F3's higher crude fat content compared to the control, the observed difference was not statistically significant ($p>0.05$). This result is likely attributed to the saturated fats in desiccated coconut, which differs from the lower fat content in tapioca (Paucean *et al.*, 2016). While the control showcases a significantly higher crude protein content than F3 ($p<0.05$), highlighting wheat's protein richness, the composite flour in F3 with tapioca shows lower protein levels (Falade & Akingbala, 2008). Moreover, F3 exhibits nearly fourfold higher crude fibre than the control ($p<0.05$) owing to desiccated coconut's fibre richness, offering nutritional benefits from aiding digestion to cholesterol reduction (Trinidad *et al.*, 2006; Dhingra *et al.*, 2012). The lower carbohydrate content observed in F3 compared to the control ($p<0.05$) indicates that tapioca has a higher carbohydrate content, which is in contrast to the lower levels found in desiccated coconut, despite its higher fat and fibre content (Oluwamukomi *et al.*, 2011).

Table 4 Proximate analysis for biscuit with best formulation (F3) and control.

Composition	F3	Control
Moisture (%)	2.33±0.37[b]	0.88±0.04[a]
Ash (%)	1.27±0.26[a]	1.27±0.07[a]
Crude Fat (%)	23.02±0.08[a]	20.26±2.28[a]
Crude Protein (%)	4.29±0.59[a]	8.11±0.29[b]
Crude Fibre (%)	4.05±0.02[b]	0.12±0.00[a]
Carbohydrate (%)	65.04±0.74[a]	69.12±2.08[b]

F3 - 30:40:30 ratios of wheat flour: tapioca flour: desiccated coconut. Mean values with the same superscript letter within the same column were not significantly different (p>0.05).

3.3 Physical evaluation of biscuit

Table 5 shows comparison between F3 and control biscuits in terms of parameters for spread ratio, texture of hardness, colour and pH. The spread ratio of F3 aligns with findings from previous studies involving flour substitutions, showcasing similarity to Sobhan *et al.* (2014) and Bala *et al.* (2015). As tapioca flour and desiccated coconut replaced conventional flours, there's a noticeable trend toward decreased size and increased thickness in biscuits. Tapioca flour, known for its higher setback value compared to wheat, correlates with this shift, leading to a thicker and smaller biscuit (Chauhan *et al.*, 2016). A lower spread ratio is preferred in biscuits for a greater snap upon biting and is indicative of desirable grain fineness, texture, and mouthfeel (Sobhan *et al.*, 2014).

Table 5 Results for physical evaluation of F3 and control biscuit.

Parameter	F3	Control
Spread Ratio	7.24[a]	7.58[b]
Hardness (N)	1.95±0.87[a]	1.83±1.09[a]
Colour:		
L	70.00±1.32[b]	67.02±0.38[a]
*a**	8.66±0.13[a]	10.23±0.06[b]
*b**	25.42±0.92[a]	27.59±0.35[b]
pH	8.33±0.06[b]	7.99±0.20[a]

F3 - 30:40:30 ratios of wheat flour: tapioca flour: desiccated coconut. Mean values with the same superscript letter within the same column were not significantly different (p>0.05).

Texture analysis plays a significant role in evaluating biscuit quality. While sensory evaluations are time-consuming, texture analyzer offer faster and quantifiable assessments. The observed increase in hardness in the biscuits with the best formulation, while not statistically significant (p>0.05) compared to the control, suggests a higher level of crispiness in the biscuits. The increased hardness of F3 can be attributed to its thicker consistency in comparison to the control, which aligns with previous research conducted (Kim *et al.*, 2011; Lu, 2013; Bala *et al.*, 2015).

When examining colour analysis through colorimetry, the lighter and less red or yellow hue in F3 compared to the control suggests differences in flour composition. The absence of red or purple pigments in the composite flours and potential degradation of yellow pigments during baking contribute to the variations observed. Studies on tapioca flour colour parameters align with the lighter and less red or yellow characteristics seen in biscuits with higher tapioca flour content, corroborating the impacts of flour composition on colour (Mamat *et al.*, 2020).

Additionally, moisture content and biscuit thickness influence colour differences, with higher initial moisture content and thicker biscuits affecting the browning process (Sandra Budzaki *et al.*, 2014). The pH differences between F3 and the control are statistically significant ($p<0.05$). The use of sodium bicarbonate as a leavening agent in both formulations contributes to their higher pH values. While ammonium bicarbonate serves as a leavening agent, its heat-induced decomposition doesn't influence the final baked product's pH, unlike sodium bicarbonate, which aids in batter distribution and pH increase by neutralizing flour acids (Vetter, 2003; Tiefenbacher, 2019).

4. Conclusion

This study explored the immense potential of tapioca flour and desiccated coconut as viable substitutes for wheat flour in creating composite flour for biscuit production. Among the various formulations tested, F3 emerged as the optimal blend, comprising wheat flour, tapioca flour, and desiccated coconut in a ratio of 30:40:30 respectively. Notably, when compared to control biscuits made solely from 100% wheat flour, F3 exhibited elevated levels of moisture, crude fibre, and carbohydrates, showcasing significant improvements. Interestingly, the levels of ash and crude fat content in F3 remained comparable to the control, signifying an enhancement in nutritional composition without compromising certain attributes. By augmenting wheat flour with alternative composite flours, this study underscores a notable improvement in both the nutritional profile of the biscuits and their overall acceptability among consumers. The exploration of these composite flours has shown promising results, highlighting their capacity not only to enrich the nutrient content of biscuits but also to enhance consumer satisfaction. The composite flours have the potential to serve as a valuable component in the formulation of gluten-free products.

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