JSTR
ASEAN Journal of Scientific and Technological Reports

Research article

Effect of Sweet Cassava Flour and Rice Flour on Physical Properties and Sensory Evaluation of Gluten-Free Takoyaki Product

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Citation:
Maneechoold, P.; Ratanasumawong, S.; Siriwong, N. Title. *ASEAN J. Sci. Tech. Report.* **2021**, *24(3)*, 27-35.

Article history:
Received: March 15, 2021
Revised: August 26, 2021
Accepted: September 1, 2021
Available online: December 28, 2021

Abstract: The objective of this research was to investigate the effect of substitution of wheat flour with sweet cassava flour and rice flour on physical and sensory qualities in a gluten-free Takoyaki. The different ratios of cassava flour and rice flour were performed at five recipes, including 55:45 (HN55), 65:35 (HN65), 75:25 (HN75), 85:15 (HN85) and 100:0 (HN100) and then analyzed their quality attributes. These results indicated that increasing the ratio of cassava flour in Takoyaki products revealed the decrease in hardness ($p \leq 0.05$) and the colour of products were a darker brown with lightness (L*) redness (a*) but yellowness (b*) was decreased ($p \leq 0.05$). Next, the sensory evaluation suggested that an increase of ratios of cassava flour was also significantly reduced in the likeness score in appearance, colour, crispness, softness, oiliness, and overall liking ($p \leq 0.05$) by using a 9-point hedonic scale. This work clearly shows that HN55 is like Takoyaki from wheat flour (as control) since the sensory evaluation has been indicated at like moderately to very much. So, the sweet cassava flour is potentially used to prepare gluten-free products, but it may be necessary to improve due to some containing the specific odour.

Keywords: Sweet Cassava Flour, Gluten-Free Product, Rice Flour, Sensory Evaluation, Physical Property, Takoyaki

1. Introduction

The increase of global consumption and behavior in starch has been reported. In 2016, the demand of starch products was around \$180 million and likely to reach \$270 million in 2022 [1]. In general, the product is mainly produced from wheat however there are still limitations of some consumers due to gluten showing the negative impacts in relation to allergies and intolerances. The increasing prevalence of gluten-related disorders has led to increasing consumer demand for gluten-free products. However, the replacement of gluten in cereal-based products is a challenge because a different flour characteristic to replace the wheat is need to be developed. There are some sources has been studied in rice flour, cassava flour, maize starch, potato starch. These works suggested that the flours are commonly used in different purposes based on the characteristics. For example, maize starch is yields gluten-free breads with higher volume and contains dry and crumbly in texture. Rice flour yields is lower volume bread but has a good texture and acceptability. Cassava and potato starches have a lower volume bread compare to maize starch, but delivers better textural attributes and acceptability by adding to a starch/flour base mixture [2].

Cassava is classified into two major groups: bitter and sweet cassava. Bitter cassava, which is not commonly used for consumption, contains a bitter taste due to hydrocyanic acid accumulation. Sweet cassava is an alternative because it contains a low hydrocyanic acid and less bitter taste [3]. Particularly, Hanatee is becoming more well-known as sweet variety in Thailand, which has been used in several processes, e.g. simple boiling, grilling, or simmering in syrup [4]. The development of sweet cassava flour is beneficial than using cassava root, but the flour can be stored and easily used in a wide range of products.

Cassava flour and starch are considered an option for replacing gluten in cereal-based products. They have widely been exploited as bakery additives in bread and other bakery products [5–7] and as thickeners and structure enhancers in different food systems [8–9]. In addition, the cheap nature and functional properties of cassava. However, cassava flour and starch in bakery production pose technological challenges. Cassava flour produces poorly-structured bakery products due to its innate gluten-free nature and its minute composition of sulfur-containing amino acids [1011]. Rice flour has been introduced as a healthier alternative providing lower calories and less risk of gluten intolerance or celiac disease compared to wheat flour. Although thicker than wheat flour, it has been reported to have better functionality in reducing fat absorption [12].

This work used sweet cassava flour to develop Takoyaki as a gluten-free product. Takoyaki is a well-known Japanese-style snack that is popular with a range from street markets to Japanese restaurants recognized. In general, wheat flour is commonly used in Takoyaki recipes. Thus, the development of sweet cassava flour to replace wheat flour is an option and it can be possible to expand to produce various gluten-free products. In this study, the development of Takoyaki making from sweet cassava flour and rice flour was investigated. This is included physical properties and texture acceptability. Moreover, Batters and Takoyaki physical, colour, textural, and organoleptic properties were also evaluated and compared with the flour Takoyaki containing gluten.

2. Materials and Methods

2.1 Materials

Hanatee cassava roots were used in these experiments grown in Kanchanaburi province, Thailand. The ingredient of Takoyaki mixed was purchased from the supermarkets in Bangkok, Thailand. Other ingredients included wheat flour (Kite, United Flour Mill Public Co., Ltd., Thailand), Rice flour and glutinous rice flour (Erawan, Cho Heng Rice Vermicelli Factory Co., Ltd., Thailand), Cornflour (McGarrett, Continental Food Co., Ltd., Thailand), pure refined sugar (Imperial, KCG Corporation Co., Ltd., Thailand), refined salt (Prung Thip, Thai Refined Salt Co., Ltd., Thailand), egg (Tops, Saeng Thong Saha Farm Co., Ltd., Thailand), ponzu sauce (Aro, ASAN Service Co., Ltd., Thailand), fresh milk (Meiji, CP-Meiji Co., Ltd., Thailand), RBD palm olein from pericarp (Morakot, Sime Darby Oils Morakot Pub Co., Ltd., Thailand), all vegetables as cabbage, carrot and bunching onion (Royal Project Foundation, Thailand) and ginger pickle (Savepak, Lengheng Agrifoods Co., Ltd., Thailand) were used in this experiment.

2.2 Cassava flour preparations

The sweet cassava roots (Hanatee) were peeled, washed and chipped to a uniform size by a chipper, and then dried in a hot air oven at 50 °C for 24 h. Dried cassava was milled by hammer mill and sifted through a 180 μm aperture sieve by a sieving machine. The sweet cassava flour was then kept at room temperature (27 ± 5 °C) for subsequent analyses [8].

2.3 Preparation of Takoyaki

The Takoyaki formula (a conventional formulation as control) was prepared by using 29.30% mix flour as follows: wheat flour: glutinous rice flour: corn flour (75:18:7), 3.00% sugar, 0.35% baking powder, 0.35% salt, 4.00% egg, 1.00% ponzu sauce, 10.00% fresh milk and 52% water. The gluten-free flour of the Takoyaki formula was prepared from the Hanatee cassava flour (HN) with the following ratios: rice flour at 55:45 (HN55), 65:35 (HN65), 75:25 (HN75), 85:15 (HN85) and 100:0 (HN100). For each formulation, samples were prepared by mixing all dry ingredients and then liquid ingredients and mixing well. The batter rested at room temperature (27 ± 3 °C) for 30 minutes. Fifty-five grams of batter was mixed with vegetable 3 gram and then fried in the Takoyaki pan containing 20 grams of oil per mold at 140 ± 10 °C for 8 to 10 min and molding on the pan until it formed a spherical shape.

2.4 Physical properties of Takoyaki batter and Takoyaki products

2.4.1 Pasting properties of control and mixed gluten-free flours

The pasting properties of the control and gluten-free flours (at a concentration of 8 g/100 g dwb) were determined with the Rapid-Visco Analyzer (RVA-4, Newport Scientific, Narrabeen, Australia). Concerning sample preparation, 2.24 g (dry weight basis) of flour samples were weighed directly into the aluminium RVA canister, distilled water was added to a total weight of 28 g, and then contents were mixed. The sample was kept at 50 **°C** for 1 min, heated to 95 **°C** at a rate of 12 **°C** /min, held at 95 **°C** for 2.5 min, cooled down to 50 **°C** at a rate of 12 **°C** /min, and held at 50 **°C** for 2.5 min. The rotational speed of the paddle was used at 160 rpm throughout the experiment. Peak viscosity, breakdown (difference between peak viscosity and minimum viscosity), final viscosity setback (difference between final viscosity and minimum viscosity) and pasting temperature were determined.

2.4.2 Physical properties of Takoyaki Batter

The rested batters (450 gram) were transferred to a 600 ml beaker and the viscosity was measured on a viscometer (model VISCO BASIC plus L, Switzerland) with an L1 spindle at 100 rpm under room temperature (25 ± 5 °C). Measurements were carried out in triplicates.

The colors of the rested batters were measured for 3 replicates using a Hunter Lab Digital Colorimeter (Color Flex model 4510, USA). The parameters were L* (L = 0 [black] and L = 100[white]), a* (–a = greenness and +a = redness), b* (–b = blueness and +b = yellowness).

2.4.3 Physical properties of Takoyaki products

Textures of the cooked Takoyaki samples were determined in a TA. XT plus texture analyzer (Stable Micro Systems, Surrey, UK) equipped with a 50 kg load cell. The parameters were calculated using the software Exponent. The test mode was configured for compression. Each sample was placed in a texture analyzer and compressed using a cylindrical probe (2 mm) at a distance of 6 mm and 5.0 g trigger force with pre-test, test, and post-test speeds at 1.0, 3.0, and 5.0 mm/s, respectively. The hardness (g) of the crust was recorded. All results were performed with ten replicates. The crust colours of the cooked Takoyaki were measured by using Hunter Lab Digital Colorimeter (Color Flex model 4510, USA) with triplicates. Parameters were determined as described that L* (L = 0 [black] and L = 100[white]), a* (−a = greenness and +a = redness), b* (–b = blueness and +b = yellowness). The browning index (BI) of the crust [13,14] was calculated according to equations $BI = 100 * (X - 0.31)/0.17$ where: $X = (a^* + 1.75L^*)/(5.645L^* + (a^* - 3.012b^*))$.

2.5 Sensory evaluation

Sensory evaluation was carried out by a group of fifty untrained panels with the follows factors; appearance, colour, crispness, overall texture, oiliness, and overall acceptability on a nine-point hedonic scale (from 9 for “like extremely” to 1 for “dislike extremely”) by using the Takoyaki prepared at temperature 40 ± 5 °C for 15 min. All samples were coded and randomly served to the sensory panel, and oral rinses were taken before tasting each Takoyaki sample.

2.6 Statistical analysis

Quantitative data are expressed as mean ± standard deviation (SD) of three replicates. The data were analysed using the SPSS statistical package (SPSS, version 12.0, Chicago, IL, USA). The difference in means, variance and Duncan's multiple were analysed at 95% significance.

3. Results and Discussion

3.1 Pasting properties of control and mixed gluten-free flours

The Rapid-Visco Analyzer of 8% (db) control and mixed gluten-free flour of the 5 recipes of Takoyaki are presented in Table 1 and Fig 1. These results demonstrated that the pasting temperature of the mixture of starch and cassava flour (in this study) was obtained at 76-77 °C but less than the original of the pasting temperature from rice (88 °C) and cassava flour (77 °C). Similarly, the pasting temperature of the mixture of wheat flour, waxy rice flour, and cornflour (as control) was contained 75 °C, although individual flour has different at 86, 70 and 79 °C, respectively.

Thus the presence of flour content determined the different pasting temperatures. Here, the cassava flour generally contains a weak intra-granular organization and rapidly swelled at low temperatures compared to rice flour with the highest pasting temperature. Consistently, wheat flour also revealed a lower pasting temperature with moderately swollen and amylose-lipid complexes compared with rice flour granules [15]. Furthermore, the HN55, HN65, HN75, HN85's peak viscosity was less than HN100 but higher than the control. In this study, added cassava flour in the mixture could be increased a number of breakdown values that reflect a low resistance to heat and shear force. This has been described by Kim et al. (1999) that the strong swelling value of starch granules mainly responds to high viscosity and easily breakdown due to the weak intermolecular force [16]. This is sensitive to the shear force after the temperature increases and starch granules were then quickly broken down by the shear force to increase the swelling power.

Table 1. Pasting parameters of control and mixed gluten-free flour formula.

Sample	Parameter				
	PV (RVU)	**BD (RVU)**	**FV (RVU)**	**SB (RVU)**	**PT (°C)**
Control	194.80^{f} ± 1.90	71.30^{c} ± 1.90	256.80^{c} ± 1.40	133.30^{a} ± 1.40	75.10^{c} ± 0.00
HN55	238.10^{b} ± 1.20	47.10^{f} ± 0.40	298.90^{a} ± 1.00	107.90^{b} ± 0.60	76.40^{b} ± 0.60
HN65	234.30^{d} ± 0.60	51.30^{e} ± 1.10	276.80^{b} ± 0.40	93.80^{c} ± 0.10	76.80^{b} ± 0.00
HN75	232.50^{e} ± 1.50	57.90^{d} ± 0.80	255.60^{c} ± 1.70	80.90^{d} ± 2.30	76.80^{b} ± 0.00
HN85	237.40^{c} ± 1.20	78.10^{b} ± 1.00	227.80^{d} ± 3.60	68.50^{e} ± 2.10	77.10^{a} ± 0.50
HN100	271.80^{a} ± 1.80	126.90^{a} ± 1.20	199.60^{e} ± 1.30	54.70^{f} ± 0.70	76.80^{b} ± 0.10

[1]Values are expressed as mean ± standard deviation (n=3). Different letters in the same column indicate a statistically significant difference ($p \leq 0.05$).

[2]RVA Parameter (PV = peak viscosity, BD = breakdown, FV = final viscosity, SB = setback, PT = pasting temperature)

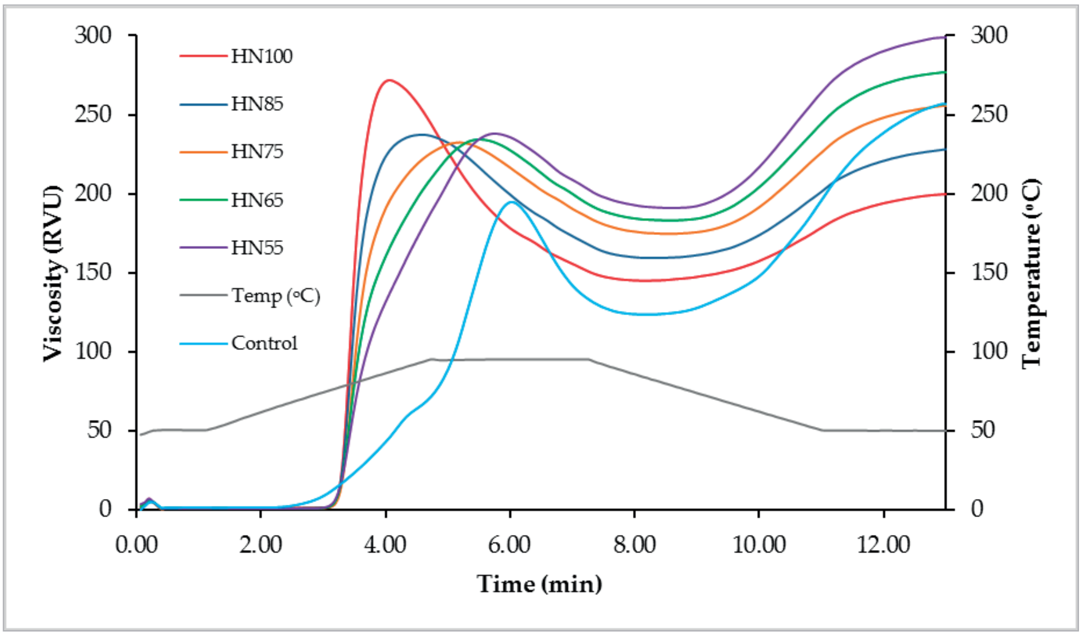

Figure 1. *Pasting profiles of control and mixed gluten-free flours by using RVA.*

Next, both final viscosity and setback are indicated in the rearrangement of excreted amylose molecules from the starch granules after swelling. It was found that HN55, HN65, HN75 and HN85 were shown higher than the HN100 and control, but the setback of control was shown the highest. The setback revealed the gelling ability or retrogradation tendency of the amylose. The increase of the ratio of cassava flour was possibly shown a lower retrogradation. Mainly, HN 100 was obtained with low final viscosity and setback. This explained that cassava flour contains amylose content less than rice flour.

3.2 Physical properties of Takoyaki Batter

In this study, the batter is defined as the composition of water, flour, and seasoning used to fly rather than deep-fat fried. As shown in Table 2, the apparent viscosity of batters containing in different gluten-free flour formula ratios and control were performed at room temperatures. It was found that all batters showed significantly different clear viscosity values at ($p \leq 0.05$). Although the control provided the highest viscosity compared to among the cassava flour formulars, the increased ratio of cassava flour could be improved the viscosity.

Table 2. Apparent viscosity and colour measurement of batters.

Batter sample	Viscosity (cP)	Colour		
		L*	a*	b*
Control	$61.19^{a} \pm 1.95$	$81.30^{c} \pm 0.05$	$2.09^{a} \pm 0.01$	$14.47^{d} \pm 0.04$
HN55	$17.26^{e} \pm 0.12$	$83.05^{a} \pm 0.12$	$1.36^{c} \pm 0.06$	$14.27^{d} \pm 0.23$
HN65	$18.08^{d} \pm 0.05$	$82.21^{b} \pm 0.05$	$1.71^{b} \pm 0.01$	$15.16^{c} \pm 0.19$
HN75	$18.40^{d} \pm 0.03$	$81.89^{c} \pm 0.04$	$1.79^{b} \pm 0.02$	$15.86^{b} \pm 0.74$
HN85	$19.53^{c} \pm 0.15$	$81.04^{d} \pm 0.08$	$2.23^{a} \pm 0.03$	$15.25^{c} \pm 0.16$
HN100	$22.76^{b} \pm 0.69$	$80.29^{c} \pm 0.03$	$2.23^{a} \pm 0.08$	$18.55^{a} \pm 0.24$

Values are expressed as mean ± standard deviation (n=3). Different letters in the same column indicate a statistically significant difference ($p \leq 0.05$).

As we demonstrated, the viscosity of the mixture of cassava flour and rice flour showed less than 3 times compared with the control. The viscosity changes may rely on the composition, e.g. water, starch, protein and/or dietary fibre, to make the viscous slurries [17]. In addition, increased water-binding and absorption capacities also directly link to the increased proportion inclusion of cassava starch into wheat starches [18]. Inclusions of cassava flour and other starches in food formulation could be affected on the other properties in the finished product, such as bread [19].

Further investigation indicated that a different proportion of cassava flour affects the colour value, which is significantly different ($p \leq 0.05$). The increased cassava flour proportions, the higher a* and b* values decreased, but L* is reduced. Table 2 shows a batter's colour value making of a different ratio of flours. The control (containing wheat flour, waxy rice flour and cornflour) revealed L* (92.20), a* (0.24) and b* (6.60) while the cassava flour obtained the L* (92.93), a* (0.04) and b* (9.69) and rice flour was L* (94.36), a* (0.22) and b* (3.41). It also noted that the change of colour value in batters could be affected by adding sugar, egg and ponzu sauce in the formula.

3.3 Physical properties of Takoyaki Products

When the batters were fried in a Takoyaki pan, the characteristics of the Takoyaki products appeared, as shown in Figure 2. The results showed that the outside appearance of Takoyaki (control) revealed it had stiffed spherical shape and no shrinked. The high proportion of cassava flour (HN55, HN65, HN75 and HN85) of Takoyaki products collapsed, especially HN100 was heavily deflated when left over for 45 minutes. It was not set, contained a clear gel appearance inside, and was too soft. Changes in the batter cause these during the frying process, heating induced starch gelatinization, protein denaturation (in the wheat flour of control) and vaporization of water in the batter leading to a crust layer forming [20]. Notedly, gluten protein in wheat flour could be influenced in a more robust and more stable structure than the batter made from cassava flour and rice flour.

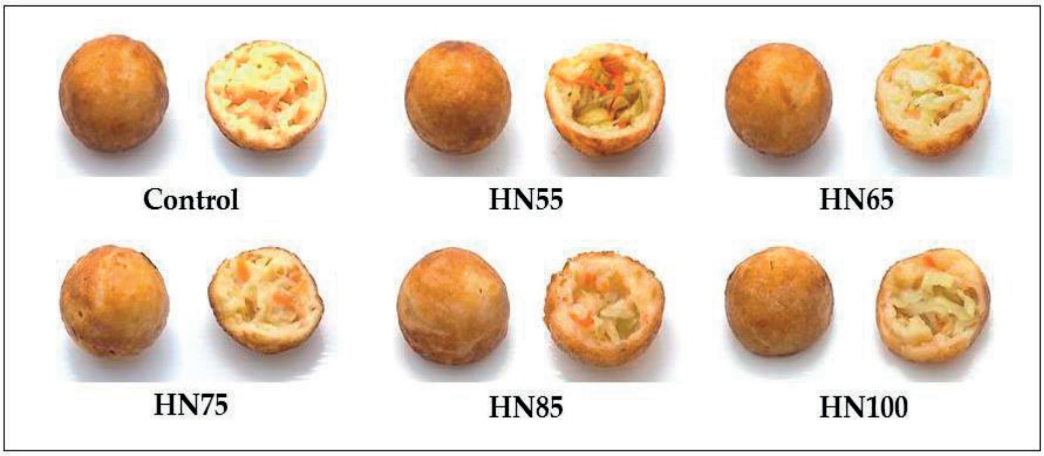

Figure 2. The Characteristics of Takoyaki products from different cassava flour and rice flour proportions.

Then, the texture of the products was analyzed using a texture analyzer. Our findings revealed that the control product obtained the highest hardness, but HN100 showed the lowest (Table 3). However, the formulas containing the increased proportion of cassava flour (HN55, HN65, HN75 and HN85) had the hardness of Takoyaki products lower than control. In particular, the HN100 formula was heavily deflated when left over a period. The inside texture was chewy, corresponding to a decrease in stiffness in proportion to the increase in cassava flour. These results respond to the texture after cooking with cassava flour. When left to cool, it would retrograde less than rice flour, thus affecting the hardness and shapest ability of Takoyaki products. This could be seen in the formula HN100, which used 100% cassava flour for Takoyaki production, had the lowest hardness and has shrinkage and shrivelled shape. The hardness showed consistency to final viscosity and setback, as shown in Table 1. It suggested that HN55 was similar to the control while HN100 had the lowest final viscosity and setback. As for the Takoyaki product, the control contained wheat flour as the main ingredient, which was relatively high in amylose, resulting in strong dough due to the chain-chain arrangement of amylose together; a fine film structure and texture of the resulting product were crisp and solid [17]. Wheat flour containing more amylose than cassava flour and rice flour affected the dryness and stiffness of the product [18].

Table 3. The hardness and colour analysis of control and gluten-free Takoyaki products.

Sample	Hardness (g.Force)	Color			
		L*	a*	b*	BI
Control	$43.46^{a} \pm 0.54$	$52.00^{a} \pm 0.54$	$11.40^{c} \pm 0.46$	$32.30^{e} \pm 0.89$	$106.52^{f} \pm 4.41$
HN55	$38.48^{b} \pm 0.49$	$41.45^{c} \pm 1.07$	$11.89^{c} \pm 0.56$	$39.40^{a} \pm 0.49$	$205.65^{a} \pm 0.66$
HN65	$26.61^{c} \pm 0.56$	$43.41^{b} \pm 1.34$	$12.74^{b} \pm 0.79$	$38.88^{b} \pm 0.56$	$186.37^{b} \pm 0.36$
HN75	$26.58^{c} \pm 0.57$	$39.87^{d} \pm 0.42$	$13.80^{a} \pm 0.70$	$33.04^{e} \pm 0.57$	$168.45^{c} \pm 0.60$
HN85	$22.23^{d} \pm 0.91$	$41.16^{c} \pm 1.45$	$12.78^{b} \pm 0.34$	$34.16^{d} \pm 1.64$	$166.43^{d} \pm 1.28$
HN100	$22.64^{d} \pm 0.69$	$43.29^{b} \pm 0.99$	$11.17^{c} \pm 0.90$	$36.13^{c} \pm 0.69$	$164.23^{e} \pm 1.63$

Values are expressed as mean ± standard deviation (n=3). Different letters in the same column indicate a statistically significant difference ($p \leq 0.05$).

In addition, the colour of the Takoyaki product was determined using a colourimeter. They were shown in colour values with significant differences ($p \leq 0.05$) (Table 3). The results indicated that the control obtained the highest L* but low in a* and b*. Then, the data was used to calculate the Browning index (BI), representing the purity of brown colour that might occur by enzymatic or non-enzymatic reaction [21]. Millard reaction is a non-enzymatic reaction that could be affected due to the mixture containing proteins and sugars derived from flour, milk, eggs and seasonings.

3.4 Sensory evaluation

Hedonic ratings for the sensory attributes of the Takoyaki samples were evaluated and shown in Table 4. It was found that the acceptability for the appearance, colour oiliness and overall liking of HN55 and control sample were not shown different ($p > 0.05$). Interestingly, HN55 is likely to be an optimal ratio because the overall is similar to control ($p > 0.05$) and with the highest level at like slightly to like moderately. In addition, the increase of cassava flour showed a negative effect on the overall texture, crispness, odour and overall liking scores. In particular, increasing the ratio up to 75% or HN75 reduced the crispness score. The lower amylose content noted that the characteristic of crust's batter after flying demonstrated stability similar to HN100. This explained that amylopectin in cassava flour could increase the surface area, lose moisture quickly, and increase the oil absorption after frying [19]. Therefore, adding less than 55% cassava flour is borderline to affect consumer preference, especially in texture, crispness, and smell.

Table 4. Sensory scores of control and gluten-free Takoyaki products.

Attribute	Takoyaki products					
	Control	HN55	HN65	HN75	HN85	HN100
Appearance	$7.35^{a} \pm 1.04$	$7.42^{a} \pm 0.90$	$6.95^{b} \pm 0.65$	$5.44^{c} \pm 0.74$	$4.36^{d} \pm 0.75$	$4.40^{d} \pm 1.23$
Color	$7.14^{a} \pm 0.99$	$7.21^{a} \pm 0.67$	$7.07^{a} \pm 0.77$	$6.64^{b} \pm 0.95$	$6.36^{b} \pm 0.85$	$6.11^{c} \pm 1.15$
Crispness	$7.56^{b} \pm 1.07$	$7.95^{a} \pm 1.87$	$7.56^{b} \pm 0.57$	$6.74^{c} \pm 0.82$	$4.98^{d} \pm 1.10$	$3.80^{e} \pm 0.87$
Texture	$7.07^{a} \pm 1.28$	$6.91^{b} \pm 0.89$	$6.69^{b} \pm 0.69$	$6.04^{c} \pm 0.72$	$4.49^{d} \pm 1.02$	$4.22^{e} \pm 1.18$
Oiliness	$6.60^{b} \pm 1.08$	$7.24^{a} \pm 0.67$	$6.56^{b} \pm 0.83$	$5.13^{c} \pm 0.72$	$4.13^{d} \pm 1.16$	$3.58^{e} \pm 1.54$
Overall liking	$7.68^{a} \pm 0.80$	$7.67^{a} \pm 1.72$	$7.35^{b} \pm 0.62$	$6.65^{c} \pm 0.73$	$6.45^{c} \pm 0.60$	$6.20^{d} \pm 0.99$

Values are expressed as mean ± standard deviation (n=3). Different letters in the same row indicate a statistically significant difference ($p \leq 0.05$).

4. Conclusions

This study demonstrated that cassava and rice flour have the potential to be replaced with wheat flour in Takoyaki products. We reported that increasing a cassava flour proportion directly negatively affected colour, crispness, and texture. The optimum condition between cassava flour and rice flour, HN55 was considered to be used in the product since it has been shown that all sensory scores at medium to high preference levels and characteristics are similar to the control.

5. Acknowledgements

This research was supported by the National Science and Technology Development Agency (NSTDA). We thank the cluster executive and research program for their kind support.

Author Contributions:

Funding:

Conflicts of Interest: The authors declare no conflicts of interest.

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