Food Sci Biotechnol (2021) 30(5):653–661
https://doi.org/10.1007/s10068-021-00909-9

RESEARCH ARTICLE

Physicochemical and sensory properties of protein-fortified cookies according to the ratio of isolated soy protein to whey protein

Hye-Rin Park[1] · Ga-Hyun Kim[1] · Yeseul Na[2] · Ji-Eun Oh[3] · Mi-Sook Cho[1]

Received: 25 July 2020 / Revised: 10 March 2021 / Accepted: 29 March 2021 / Published online: 6 May 2021

Abstract A high-protein diet has a variety of beneficial effects and mixing isolated soybean protein (ISP) with whey protein (WP) reported to increases health and functional advantages. The objective of this study was to determine an adequate ratio for mixing these two proteins by evaluating the physical and sensory properties of protein-fortified samples. Samples with 5 different ratios of ISP to WP ranging from 100:0 to 0:100 were prepared. Proximate composition, density, spread factor, hardness and color values of five samples were measured and consumer acceptance test were conducted by 117 panelists to evaluate physicochemical and sensory properties of protein-fortified cookies. In a consumer acceptance test, the combination of ISP and WP increased consumer acceptance, and the highest overall acceptance was obtained when ISP and WP were used in a one to one ratio. As the ISP content increased, the density was higher, and the spreadability was the lowest. On the other hand, as WP increased, hardness increased significantly, and L*, a* and b* values increased ($p < 0.05$).The result of this study may facilitate the development of protein-enriched foods, which have various health benefits.

Keywords Protein fortification · Cookie · Isolated soybean protein · Whey protein · Physicochemical · Consumer acceptability

✉ Mi-Sook Cho
misocho@ewha.ac.kr

Hye-Rin Park
gpfls001@nate.com

Ga-Hyun Kim
kgh813@ewhain.net

Yeseul Na
0f35@kcu.ac.kr

Ji-Eun Oh
oje96@ewha.ac.kr

[1] Department of Nutritional Science and Food Management, Ewha Woman's University, Seoul 03760, Korea

[2] Department of Food and Nutrition, KC University, Seoul 07661, Korea

[3] College of Science & Industry Convergence, Ewha Woman's University, Seoul 03760, Korea

Introduction

As people are becoming increasingly concerned about their health, there is a growing interest in more balanced meals than in food intake itself. A high-protein diet has beneficial effects, such as increasing thermogenesis and improving blood glucose control (Layman & Baum, 2004). Consumers prefer functional products that are portable and easy to ingest and have enhanced nutritional value. High protein snacks have been sold and distributed as foods for weight control and building muscle, but recently, high-protein foods have been developed for people with diabetes, obesity and protein deficiency (Chen et al., 2010; Elia et al., 2006). According to the 2019 Food labeling standards of the Ministry of Food and Drug Safety, "High protein" refers to a protein content of more than 11 g/100 g food. The global functional protein market was estimated at 823.9 kilotons in 2016. The soy protein ingredients market is projected to grow at a CAGR of 7.2% from 2017 to 2022, to reach USD 12.8 billion by 2022. Cookies are small, flat, sweet, baked goods, usually containing flour, eggs, sugar, and either butter, cooking oil or another oil or fat (Abayomi and Oresanya et al., 2013; Adeyeye and Akingbala, 2015). Also, cookies are sweet and crispy, and it is a food that is used habitually as a main snack for children, young women and the elderly since it goes well with drinks. Moreover, it has low moisture content and low microbial deterioration which is one of the excellent advantages for storage and easy to carry (Cho et al., 2006). Therefore, the tendency of consumers preferring such health-oriented foods is leading to the development of new cookies containing nutrients and functional ingredients added to existing cookie products.

The two most common protein sources used in the development of high-protein products are isolated soybean protein (ISP) and whey protein (WP) (Kim, 2016; Martin et al., 2019). According to Kim (2016), most protein-based functional foods in Asian countries, including Korea, rely on soybean protein, while in the United States, whey is the most common source of protein although functional foods containing more diverse proteins (for example, ISP and whey) are available. Whey protein and soy protein are both used in a variety of applications to improve functionality, and currently, they are extensively used to improve the nutritive properties of foods (Russell et al., 2006).

ISP, while it is a vegetable protein, has a high protein digestibility-corrected amino acid score and can thus be viewed as a purified whole protein. Notably, ISP contains high levels of glutamine and arginine and has a low carbon content, making it a promising protein source for future applications (Hughes et al., 2011). In addition, research has reported that ISP improves antioxidant activity (Hagen et al., 2009) and helps in the treatment of diabetes (Mendes et al., 2014). Therefore, ISP is often used in products to fortify protein (Akesowan, 2010). Whey is obtained as a byproduct during the production of cheese; in addition to protein, it contains immune complexes, including lactoferrin, as well as minerals, such as calcium. Despite its low heat stability upon sterilization, its high digestion-absorption rate makes it popular for protein enrichment or improving satiety in the food industry (Kim, 2016). Whey protein has a benefit in protein value, bioavailability and absorption rate (Kalman, 2014).

By mixing ISP and WP, the major sources of protein for functional foods, an enriched amino acid composition and enhanced antioxidant functions can be obtained owing to the complementary properties of the two protein sources. In addition to these benefits, improved digestion-absorption rates and periods of satiety have been reported for such mixtures (Paul, 2009). Additionally, ISP is suitable as a protein reinforcing material because it has a higher production volume and the supply is stable (Kim, 2018). It is relatively inexpensive price compared to other protein materials.

In recent years, the demand for protein-fortified products is increasing in Asia, but products that use multiple complementary protein sources are rare and have not been actively evaluated. Most of the research done is also using a single material rather than a blending ISP and WP. There are previous studies using a single material to fortify protein, including studies about biscuits (Rababah et al., 2006), ice cream (Friedeck et al., 2003) and yogurt (Drake & Gerard, 2003). Thus, the objective of this study was to determine an adequate ratio for mixing these two proteins after evaluating the physical and sensory properties of protein-fortified samples. The results of this study provide fundamental information for the development of protein-fortified cookies.

Materials and methods

Materials

ISP powder was obtained from Suihua Jinlong Vegetable Oil Co. Ltd. (Heilongjiang, China). WP powder was obtained from Milk Specialties Global (Eden Prairie, MN, USA). Rice bran powder was purchased from Malgundle Co., Ltd. (Kang-won, Korea). Other ingredients, including wheat flour (CJ Cheiljedang, Yangsan, Korea), butter (Fonterra Limited Co., Auckland, New Zealand), vanilla extract (Bread Garden Co., Seoul, Korea), oligosaccharides (CJ Cheiljedang, Incheon, Korea), bay salt (CJ Cheiljedang, Sinahn, Korea), and eggs, were purchased from a local market (Seoul, Korea).

Preparation of cookie samples

Protein-fortified cookies with various ratios of ISP and WP were prepared according to the creaming method (AACC, 2000). The ratio of each material and the composition ratio between protein materials determined through preliminary experiments were as follows (Table 1). Of the total percentage, protein-enhanced materials (total amount of ISP and WP) were 30%, wheat 27%, butter 25%, oligosaccharides 20%, egg yolk 17%, rice bran 3%, salt 0.3%, and vanilla extract 0.1%. The cookies were prepared as follows (Table 2). Butter was creamed using a kneader (KitchenAid, Benton Harbor, MI, USA), and oligosaccharides, salt, separated egg yolk, and vanilla extract were added and mixed until the mixture became creamy. Sieved flour, rice bran powder, and the protein source were added and thoroughly mixed. The following five protein compositions were evaluated (labeled according to the proportion of ISP): 100% ISP (ISP100); 75% ISP and 25% WP (ISP75); 50% ISP and 50% WP (ISP50); 25% ISP and 75% WP (ISP25); and 100% WP (ISP0). The dough was formed into a long, rectangular rod of 2.5 cm × 2.5 cm and placed in a refrigerator at 4 °C for 1 h. Afterwards, the dough was cut to a thickness of 1 cm and baked for 11 min on parchment

Table 1 Compositions of cookies with different ratios of isolated soy protein (ISP) to whey protein (WP) (Units: g)

Ingredients	Samples[1]				
	ISP100[1)]	ISP75[2)]	ISP50[3)]	ISP25[4)]	ISP0[5)]
ISP (Isolated soy protein)	30 (100%)[2]	22.5 (75%)	15 (50%)	7.5 (25%)	0 (0%)
Whey protein	0 (0%)	7.5 (25%)	15 (50%)	22.5 (75%)	30 (100%)
Wheat flour	27	27	27	27	27
Butter	25	25	25	25	25
Oligosaccharides	20	20	20	20	20
Egg yolk	17	17	17	17	17
Rice bran	3	3	3	3	3
Salt	0.3	0.3	0.3	0.3	0.3
Vanilla extract	0.1	0.1	0.1	0.1	0.1

[1] 100% Isolated soy protein was added to cookies

75% Isolated soy protein and 25% whey protein were added to cookies

50% Isolated soy protein and 50% whey protein were added to cookies

25% Isolated soy protein and 75% whey protein were added to cookies

100% Whey protein was added to cookies

[2] (%): Percentage of total protein (total: 30 g)

Table 2 Proximate compositions of the protein powders

Properties	Protein powder added to cookies	
	Isolated soy protein	Whey protein
Moisture (% dry matter basis)	5.74	5.20
Crude protein (% dry matter basis)	89.22	85.54
Crude fat (% dry matter basis)	0.49	6.45
Crude ash (% dry matter basis)	4.55	2.81

paper in a preheated oven (Dae Yung Machinery Co., Seoul, Korea) with a top heat of 180 °C and bottom heat of 140 °C. The baked dough was cooled for 1 h at 20 °C.

Proximate analysis

The proximate analysis of the protein powders and the cookies with different ratios of ISP to WP were performed according to the AOAC method (AOAC, 2005). The moisture content was analyzed by oven-drying at 105 °C. The crude protein content was analyzed by the micro-Kjeldahl method. Crude fat content was determined by the Soxhlet extraction method. Crude ash content was determined by direct ashing at 550 °C. Mean values were obtained for each sample from three replicate measurements. The carbohydrate content was calculated by subtracting the average contents (%) of moisture, crude protein, crude fat, and crude ash from the total sample prior to analysis, which was set to 100%.

Physical property evaluation

Density

The density of cookie dough was calculated as the ratio of the weight to the volume as determined by placing 5 g of cookie dough into a 50-mL measuring cylinder containing 30 mL of distilled water (g/mL).

Spread factor

The spread factor was defined as the ratio between the height and diameter of the cookie according to the AACC Method (2000). The cookie diameter was calculated by horizontally lining up six cookies, measuring the total length, rotating each cookie 90°, and measuring the total length again. The lengths were divided by six to obtain the average diameter of a single cookie. The average height was calculated by vertically arranging six cookies, measuring the total height, altering the order of cookies, and measuring the total height again.

Color

The color values were obtained using a spectrophotometer (CM-3500D; Konica Minolta, Tokyo, Japan) at the center of the cookie. L* (lightness), a* [(+) redness/(−) greenness], and b* [(+) yellowness/(−) blueness] were measured.

Hardness

The hardness was measured at the center of the cookie using a texture analyzer (TACT2i; Stable Microsystems LTD., Godalming, UK). The measurement conditions were as follows: probe, stainless steel rod (diameter 10 mm); test mode, measure force in compression; option, return to start; pretest speed, 1.00 mm/s; test speed, 1.00 mm/s; posttest speed, 10.00 mm/s; target mode, distance 5.00 mm; trigger force, 5.0 g.

Consumer acceptance test and sensory evaluation

For this consumer acceptance test, 120 untrained panelists (20–29 years old) were recruited in South Korea. The study was reviewed and approved by the EWHA Univ. IRB and informed consent was obtained from each subject prior to their participation in the study (IRB no. 142–20). Out of the 120 panelists, the answer sheets of 3 panelists were incomplete. Therefore, the results of only 117 panelists (59 females and 58 males) were collected and reported.

Each panelist received five cookies with various ratios of ISP and WP ranging from 100:0 to 0:100 in 25% increments. The cookies used in the test were bite-sized (circular shape with a diameter of 5 cm) and were individually presented in a sealed container (Polyethylene terephthalate, PET plastic container) labeled with a random three-digit number. Five samples were provided in random order, water was served as a palate cleanser before and between tasting the cookies.

Panelists were asked to taste the samples and to score their overall acceptance, appearance, color, texture and flavor using a 9-point hedonic scale (score 1: Dislike Extremely; score 3: Dislike Moderately; score 5: Neither Dislike nor Like; score 7: Like Moderately; score 9: Like Extremely). After tasting each sample, they were also asked to complete a Check-All-That-Apply (CATA) questionnaire indicating the reasons for liking and disliking. Terms used in the CATA were selected by the authors based on results from a previous study (Lazo et al., 2016; Meyners et al., 2013) and a pilot study.

Statistical analysis

All physicochemical test results were obtained in triplicate. All the values are expressed as the means ± standard deviation and were analyzed by analysis of variance (ANOVA) using SPSS (Ver. 19.0 for Windows, SPSS, Inc., Chicago, IL, USA) for each attribute. Duncan's multiple range tests were used to evaluate differences among test groups with a level of significance of $p < 0.05$.

To identify the reasons for liking and disliking, the frequency of the selection of each CATA term was determined by counting the number of panelists that checked that term to describe each sample. Correspondence analysis (CA) was performed on the CATA frequency counts above 20% of respondents, and the results are presented as a symmetric plot using XLSTAT (Paris, France).

Results and discussion

Proximate composition

The proximate compositions of the protein-fortified cookies with various ratios of ISP to WP are presented in Table 3. The average crude protein content across all five samples was high at 26.66%. The crude protein content was highest for ISP100 (27.68%) and lowest for ISP0 (25.72%), indicating that a higher proportion of ISP powder corresponded to a higher crude protein content ($p < 0.001$). The crude ash content was highest for ISP100 (1.89%) and lowest for ISP0 (1.36%). Crude ash contents are known to increase upon the addition of protein powder (de Almeida Marques et al. 2016). In this study, the crude ash increased as the ISP powder content increased ($p < 0.001$), and significant differences were observed between all groups except ISP25 and ISP0. The average carbohydrate content across all five samples was 40.93%. Moisture content and crude fat were not significant between samples.

Physical properties

Density of cookie dough

The density of cookie dough with various ratios of ISP to WP are presented in Table 3. The density of cookie dough is known to decrease when protein powder is added (Singh & Mohamed, 2007). The highest density (1.16 g/mL) was observed for ISP100, and the lowest density (1.06 g/mL) was observed for ISP0, suggesting that the dough density increased as the content of ISP powder increased and the content of WP powder decreased. In previous studies, the density and hardness parameters of cookies are inversely

Table 3 Proximate compositions, densities, spread factors, hardness values, and color values of cookies with different ratios of isolated soy protein (ISP) to whey protein (WP)

Properties	Samples[1]				
	ISP100	ISP75	ISP50	ISP25	ISP0
Moisture[NS] (% dry matter basis)	9.13 ± 0.64[2]	8.87 ± 0.31	8.60 ± 0.40	8.47 ± 0.12	8.47 ± 0.58
Crude protein* (% dry matter basis)	27.68 ± 0.22[a]	26.96 ± 0.26[b]	26.58 ± 0.25[bc]	26.34 ± 0.44[c]	25.72 ± 0.19[d]
Crude fat[NS] (% dry matter basis)	21.33 ± 1.10	21.67 ± 1.21	22.07 ± 1.21	22.33 ± 1.03	23.20 ± 1.51
Crude ash* (% dry matter basis)	1.89 ± 0.07[a]	1.72 ± 0.08[b]	1.53 ± 0.03[c]	1.42 ± 0.02[d]	1.36 ± 0.05[d]
Carbohydrate[3] (% dry matter basis)	39.97 ± 1.44	40.78 ± 1.44	41.22 ± 1.46	41.44 ± 1.40	41.25 ± 1.73
Density (g/mL)*	1.16 ± 0.03[a]	1.15 ± 0.02[a]	1.13 ± 0.03[ab]	1.10 ± 0.01[b]	1.06 ± 0.01[c]
Spread factor (cm)*	41.25 ± 0.33[2c]	41.24 ± 0.22[d]	42.21 ± 0.59[c]	45.03 ± 0.77[b]	46.58 ± 0.09[a]
Hardness (gf)*	596.63 ± 25.57[d]	705.30 ± 22.27[c]	739.60 ± 51.13[c]	795.80 ± 10.24[b]	852.73 ± 29.71[a]
L^*	71.74 ± 0.25[6)bc2]	72.42 ± 0.43[b]	71.49 ± 0.35[c]	73.92 ± 0.18[a]	74.41 ± 0.68[a]
a^*	7.01 ± 0.14[b]	7.56 ± 0.27[b]	9.20 ± 0.16[a]	9.19 ± 0.17[a]	9.52 ± 0.57[a]
b^*	34.47 ± 0.11[d]	35.60 ± 0.28[c]	37.10 ± 0.19[b]	38.50 ± 0.70[a]	38.74 ± 0.26[a]

[NS]: Values are not significantly different at $p < 0.05$

a–d: Different letters within a row indicate significant differences at $p < 0.05$ by Duncan's multiple range test

L: Degree of lightness (black 0 ↔ 100 white)

a: Degree of redness (green—↔ + red)

b: Degree of yellowness (blue—↔ + yellow)

[1]100% Isolated soy protein

75% Isolated soy protein and 25% whey protein

50% Isolated soy protein and 50% whey protein

25% Isolated soy protein and 75% whey protein

100% Whey protein

[2]Mean ± S.D. (n = 3)

[3]100 − (moisture + crude protein + crude fat + crude ash)

*$p < 0.05$

correlated, and the lower the density, the higher the hardness, which negatively impacts the level of acceptance (Cho et al., 2006). The same result was found in this study. The ISP100 dough was the most difficult to knead, as its high density resulted in easier crumbling; even after baking, the resulting cookies crumbled more easily compared to other samples. The ISP0 dough was the easiest to knead, as it had the lowest density, but the texture of the cookies after baking was hard.

Spread factor

The spread factors of the protein-fortified cookies with various ISP-to-WP ratios are presented in Table 3. The spread factor refers to the tendency of the thickness of the dough to decrease and the diameter to increase when the cookie is baked in an oven (Cha et al., 2014); it is influenced by the viscosity, moisture content, and protein content of the dough (Choi, 2009). When cookie dough is baked, the water evaporate and the dryness of the dough increases (Moon & Jang, 2011). The spread factor was lowest for ISP100 (5.32) and highest for ISP0 (5.67), indicating a significant increase in the spread factor as the WP powder content increased and the ISP powder content decreased ($p < 0.001$). Among the five samples, ISP100 had the highest moisture content and the highest dough density, which is consistent with the results of prior studies showing that a lower spread factor is associated with a higher moisture (Kim & Park, 2008) and lower dough density (Faridi, 1994).

Hardness

The hardness values of the protein-fortified cookies with various ISP-to-WP ratios are presented in Table 3. The hardness of a cookie is reported to decrease upon the addition of ISP powder and increase upon the addition of WP powder (Adeyeye et al., 2017). The results of this study were consistent with these previous reports, i.e., the hardness was lowest for ISP100 (596.65 gf) and highest for ISP0 (852.72 gf), and hardness increased as the ISP powder content decreased and the WP powder content increased. Thus, the addition of ISP powder reduces hardness and increases crumbling, while the addition of WP powder increases hardness. The hardness of the cookies is influenced by moisture, air space formation, gluten, and other ingredients (Lee et al., 2006), with the moisture content having the greatest influence (Jung & Lee, 2011). In general, the hardness of a cookie decreases as the moisture content increases (Kim, 1998; Lim et al., 2009). The results of this study were consistent with these reports, as the hardness was lower for ISP100, which had a high moisture content, than for ISP0, which had a relatively low moisture content.

Color values

The color values of the protein-fortified cookies with various ISP-to-WP ratios are presented in Table 3. The L* value, which indicates the lightness of a sample, was highest for ISP0 (74.41), followed by ISP25, ISP75, ISP100, and finally by ISP50, which exhibited the lowest L* value (71.49). The color of the cookie, when all other conditions are constant, is strongly influenced by the sugar content, especially by caramelization due to the low heat stability of sugars and by the Maillard reaction, i.e., nonenzymatic browning caused by reduced sugars (Park et al., 2005). These reactions require extremely high temperatures and therefore involve considerable changes in color at the food surface during thermal treatment. The baking state of the cookies has a strong influence on their lightness. The cookie samples prepared in this study varied only in their protein contents and not in their sugars or heat exposure, explaining the lack of a trend in the L* values. The a* values, which indicate redness, were significantly lower for ISP100 (7.01) and ISP75 (7.56) than for ISP50 (9.20), ISP25 (9.19), and ISP0 (9.52) ($p < 0.001$). The b* value, which indicates yellowness, was highest for ISP0 (38.74) and lowest for ISP100 (34.47) and tended to increase as the WP powder content increased and the ISP powder content decreased. Consistent with these results, b* values have been reported to decrease upon the addition of ISP powder (Singh & Mohamed, 2007) and increase upon the addition of WP powder (de Almeida Marques et al., 2016). This may be explained by previous results indicating that the natural color of the ingredients influences the color values of the product (Jung & Lee, 2011).

Consumer acceptance evaluation of the cookies

The consumer acceptability of the protein-fortified cookies with various ratios of ISP to WP are summarized in Table 4. Based on ANOVA, the prepared samples differed significantly with respect to tested parameters of consumer acceptability ($p < 0.05$). Overall consumer acceptability was highest for ISP50 (5.06 ± 1.74), followed by ISP100 (4.95 ± 2.06), with no significant differences between these two groups ($p > 0.05$), and overall acceptability was lowest for ISP0 (3.47 ± 1.76). The appearance and color acceptability were highest for ISP0 (5.96 ± 1.69 and 6.14 ± 1.46, respectively), followed by ISP25 (5.82 ± 1.65 and 6.11 ± 1.55), and the values for these two groups did not differ significantly ($p > 0.05$). For texture acceptability, ISP100 showed the highest value (5.23 ± 2.23), followed by ISP50 (4.59 ± 1.90), with a significant difference between the two samples ($p < 0.001$). In terms of flavor, the order of the samples in decreasing acceptability was ISP50 (5.88 ± 1.75), ISP100 (5.67 ± 1.77), ISP25 (5.29 ± 1.95), ISP0 (4.98 ± 1.96), and ISP75 (4.77 ± 2.02), with significant differences between all pairs of samples ($p < 0.001$).

The overall acceptability, flavor acceptability were the highest for ISP50, in which ISP and WP powders were present in equal proportions. The second highest acceptability was for ISP100, although ISP0 and ISP25 were superior with respect to appearance and color, suggesting that WP powder is important for producing cookies with suitable appearance and color for consumers. The strongest acceptance of texture was obtained for ISP100, followed by ISP50; it is possible that the addition of ISP powder increased the softness of the cookies, thereby increasing consumer acceptance with respect to texture.

Correspondence analysis

Terms with frequencies greater than 20% were shown as symmetric plots by correspondence analysis(CA). The reasons for liking and disliking the five samples are shown in Fig. 1.

Figure 1 shows a representation of the cookies and the reasons for liking and disliking in the first and second dimensions of the CA of the CATA counts. Dimension 1 explained 51.32% of the total variation, and dimension 2 represented an additional 27.77% of the variation. In terms of liking, characteristics such as 'moist', 'texture', 'color', 'mild flavor', 'grain flavor', 'good for health', 'light' and 'familiar' are in the positive direction of the F1 axis, and the negative direction of the F1 axis includes 'appearance'

Table 4 Consumer acceptances of cookies with different ratios of isolated soy protein (ISP) to whey protein (WP)

	Samples[1]				
	ISP100	ISP75	ISP50	ISP25	ISP0
Overall acceptance***	4.95 ± 2.06[a23]	3.89 ± 1.61[bc]	5.06 ± 1.74[a]	4.29 ± 1.85[b]	3.47 ± 1.76[c]
Appearance*	5.70 ± 1.77[ab]	5.26 ± 1.91[b]	5.56 ± 1.88[ab]	5.82 ± 1.65[a]	5.96 ± 1.69[a]
Color**	5.67 ± 1.77[ab]	5.38 ± 1.90[b]	5.82 ± 1.80[ab]	6.11 ± 1.55[a]	6.14 ± 1.46[a]
Texture***	5.23 ± 2.23[a]	3.82 ± 2.06[c]	4.59 ± 1.90[b]	3.62 ± 2.12[c]	3.02 ± 1.78[d]
Flavor***	5.62 ± 1.89[ab]	4.77 ± 2.02[d]	5.88 ± 1.75[a]	5.29 ± 1.95[bc]	4.98 ± 1.96 [cd]

9-point Hedonic scale (1 = extremely dislike, 9 = extremely like)

[1]100% Isolated soy protein

75% Isolated soy protein and 25% whey protein

50% Isolated soy protein and 50% whey protein

25% Isolated soy protein and 75% whey protein

100% Whey protein

[2]Mean ± S.D. (n = 117)

[3]a–d: Different letters within a row indicate significant differences at $p < 0.05$ by Duncan's multiple range test

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

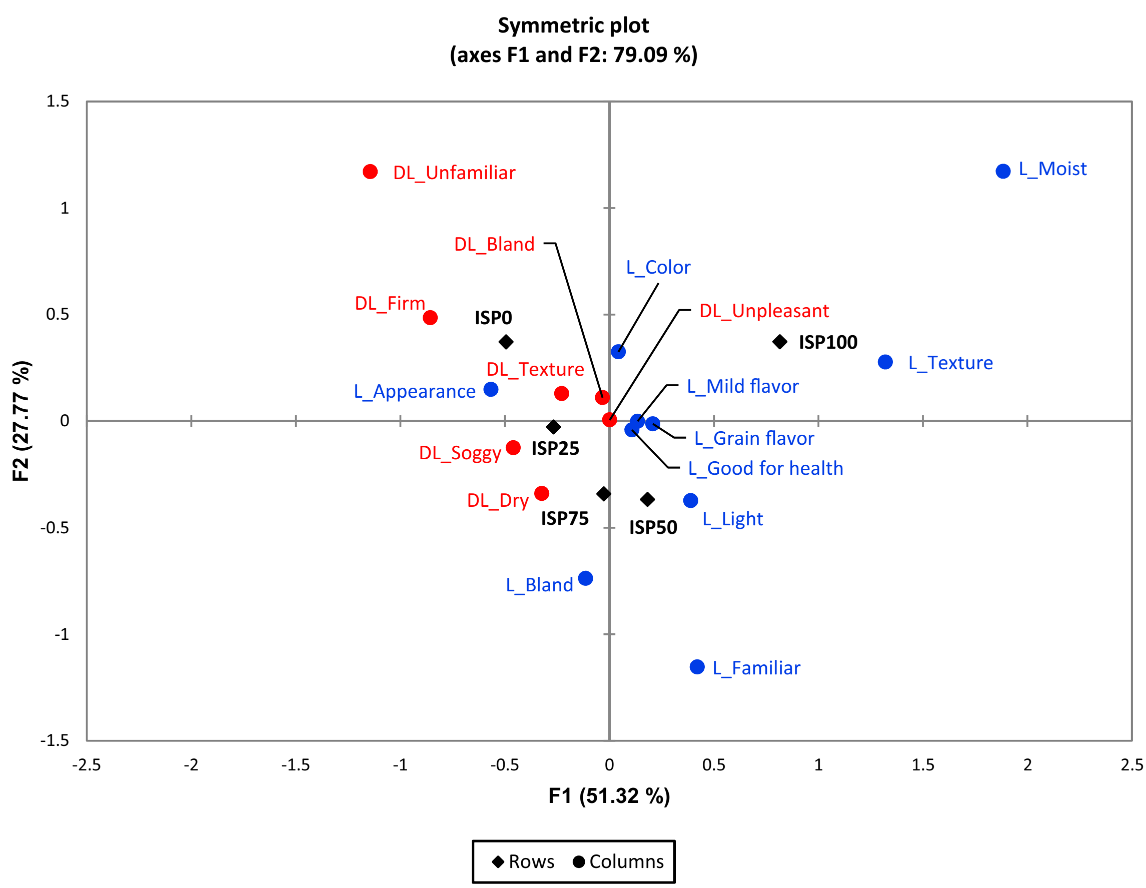

Fig. 1 Representation of the samples and the reasons for liking or disliking in the first and second dimensions of the correspondence analysis of the CATA counts ('L' refers liking, 'DL' refers disliking)

and ‘bland’. When the characteristics and the position of the samples are compared, common reasons for liking of the cookies are ‘mild flavor’, ‘grain flavor’ and ‘good for health’. Previous studies reported that grain flavor is associated with soy protein (Russell et al., 2006; Childs et al., 2007; Kreger et al., 2012). The ISP50 and ISP100 samples were especially preferred because they had characteristics such as ‘familiar taste’. This result is consistent with the study suggesting that most consumers prefer to consume familiar foods (Tuorila et al., 2001; Dovi et al., 2018). In addition to ’familiar taste’ for ISP100, ’moist’ and ’texture’ were also investigated for liking reasons. It was reported that the moisture content increases when the isolated soy protein powder was added (Singh & Mohamed, 2007). Also, the increase in the level of isolated soy protein in the maize flour showed higher water binding capacity (Adeyeye et al., 2017). This might have affected ‘moist’ and ‘texture’ of ISP100, and it leads higher overall preference in consumer test. The increase in the level of soy protein isolate in the maize flour cookies were significantly different from each other for texture and crispiness in sensory analysis (Adeyeye et al., 2017). While ISP0, which had the lowest overall acceptance, was preferred for ‘color’ and ‘appearance’.

In terms of disliking, ’unpeasant’ characteristic is in the positive direction of the F1 axis, and ‘unfamiliar’,’bland’, ‘firm’, ‘texture’, soggy’ and ‘dry’ are in the negative direction of the F1 axis. When the characteristics and the positions of the samples are compared with each other, the common reasons for disliking the cookies are ‘texture’, ‘bland’ and ‘unpeasant’. The ISP0 samples, which scored the lowest in overall acceptance, is non-preferred because they had characteristics such as ‘unfamiliar taste’, ‘texture’, and ‘firm’. Unlike the results of this study, Childs et al. (2007) report that protein bar studies conducted in the West showed both 100% whey sample and 50% whey, 50% soy sample were significantly higher overall acceptance than ISP 100. Indeed, the flavor of whey is not a familiar flavor to Asians compared to Westerners. This result is consistent with the hardness results (ISP0 is the hardest), and the hardness of a sample is believed to affect the consumer acceptance score. In a previous study, the acceptance scores were low in cookies with high hardness scores (Zoulias et al., 2000).

The result of the study showed that mixing ISP and WP could increase consumer acceptance when producing protein-fortified cookies. The density of ISP50 and ISP100 with high acceptability was higher than those of ISP25 and ISP0 samples with WP75% or higher, and their spreadability was relatively low. In terms of hardness, ISP100 was significantly lower than ISP50. L*, a*, b* showed significant differences as the WP ratio increased, but not in color and appearance acceptance. The overall acceptance of ISP50 and ISP100 was high, whereas the acceptance for texture was significantly higher in ISP100. According to Correspondence analysis (CA) results, the common reasons to like cookies were ‘mild flavor’, ‘grain flavor’ and ‘good for health’, and the special reason for the ISP50 and ISP100 is ‘familiar taste’. On the other hand, the common reasons for disliking the cookies were ‘texture’, ‘bland’ and ‘unpeasant’.

Our results confirmed that the physicochemical properties of cookies were dependent on the types of protein used when the overall protein content remained constant. WP was higher in crude fat than ISP, which affected the density, spreadability and texture of the product after baking. Familiarity has a positive effect on food acceptance, and the flavor of whey was unfamiliar to Asians, but if mixed with ISP, it could appeal to Asians enough.

In this study, quality characteristics and acceptability were measured according to the ratio of protein materials, and it was meaningful to suggest quality characteristics and acceptance for the combined use of protein materials. However, it was not possible to compare the quality characteristics and acceptability between the fortified product with the wheat flour based product not fortified with protein. In the follow-up research, the quality characteristics of products should be investigated depending on whether or not protein is fortified, and the research results will contribute to improving the quality and preference of protein-enhanced products.

Acknowledgements This work was supported by the Korea Institute of Planning and Evaluation for Technology in Food, Agriculture, Forestry and Fisheries (iPET), and is part of high value-added food development project [Grant Nr 2-2016-1903-001-2].

Author Contributions HRP and JEO conducted to determine protein source ratios, made the Protein-Fortified Cookies, performed the statistical analysis, and wrote the first draft. GHK and YN collected data and revise a manuscript. MSC designed the study, provided the funding, supervised the project.

Declarations

Conflict of interest The authors declare no conflict of interest.

References

AACC International. Approved methods of the AACC. 10th ed. American Association of Cereal Chemists, AACC International, St.Paul, MN, USA (2000)

Abayomi HT, Oresanya TO, Opeifa AO, Rasheed TR. Quality evaluation of cookies produced from blends of sweet potato and fermented soybean flour. International Journal of Agricultural, Biosystems Science and Engineering Vol: 7 (7) 350–355 (2013)

Adeyeye, Samuel Ayofemi, and John O. Akingbala. Quality characteristics and acceptability of cookies from sweet potato–maize flour blends. Nutrition & Food Science. 703–715 (2015) doi:https://doi.org/10.1108/NFS-03-2015-0020

Adeyeye SAO, Adebayo-Oyetoro AO, Omoniyi SA. Quality and sensory properties of maize flour cookies enriched with soy protein isolate. Cogent Food & Agriculture. 3: 1278827 (2017)

Akesowan A. Quality characteristics of light pork burgers fortified with soy protein isolate. Food Science and Biotechnology. 19: 1143-1149 (2010)

AOAC. Official methods of analysis. 17th ed. Association of Official Analytical Chemists Official Methods of Analysis, Rockville, USA (2005)

Cha SS, Jung HO, Son HK, Lee JJ. Physicochemical and sensory characteristics of cookies with added purple kohlrabi powder. Korean Journal of Food Preservation. 21: 824-830 (2014)

Chen MJ, Jovanovic A, Taylor R. Utilizing the second-meal effect in type 2 diabetes: practical use of a soya-yogurt snack. Diabetes Care. 33: 2552-2554 (2010)

Childs JL, Yates MD, Drake MA. Sensory properties of meal replacement bars and beverages made from whey and soy proteins. Journal of Food Science. 72: S425-S434 (2007)

Cho HS, Park BH, Kim KH, Kim HA. Antioxidative effect and quality characteristics of cookies made with sea tangle powder. Journal of The Korean Society of Food Culture. 21: 541-549 (2006)

Choi HY. Antioxidant activity and quality characteristics of pine needle cookies. Journal of the Korean Society of Food Science and Nutrition. 38: 1414-1421 (2009)

de Almeida Marques G, de São José JFB, Silva DA, da Silva EMM. Whey protein as a substitute for wheat in the development of no added sugar cookies. LWT. 67: 118-126 (2016)

Dovi KA, Chiremba C, Taylor JR, de Kock HL. Rapid sensory profiling and hedonic rating of whole grain sorghum-cowpea composite biscuits by low income consumers. Journal of the Science of Food and Agriculture. 98: 905-913 (2018)

Drake MA, Gerard PD. Consumer attitudes and acceptability of soy-fortified yogurts. Journal of Food Science. 68: 1118-1122 (2003)

Elia D, Stadler K, Horváth V, Jakus J. Effect of soy-and whey protein-isolate supplemented diet on the redox parameters of trained mice. European Journal of Nutrition. 45(5), 259-266 (2006)

Faridi H. The science of cookie and cracker production. Chapman and Hall, NY, USA. pp. 237–238 (1994)

Friedeck KG, ARAGUL-YUCEER YK, Drake MA. Soy protein fortification of a low-fat dairy-based ice cream. Journal of Food Science. 68: 2651-2657 (2003)

Hagen MK, Lehenbauer-Lüdke AR, Paludo AC, Schenkel P, Gonçalves L, Fernandes TG, Caron R, Llesuy S, Mill JG, Belló-Klein A. Diet with isolated soy protein reduces oxidative stress and preserves ventricular function in rats with myocardial infarction. Nutrition, Metabolism and Cardiovascular Diseases. 19: 91-97 (2009)

Hughes GJ, Ryan DJ, Mukherjea R, Schasteen CS. Protein digestibility-corrected amino acid scores (PDCAAS) for soy protein isolates and concentrate: Criteria for evaluation. Journal of Agricultural and Food Chemistry. 59: 12707-12712 (2011)

Jung KJ, Lee SJ. Quality characteristics of rice cookies prepared with sea mustard (Undaria pinnatifida Suringer) powder. Journal of the Korean Society of Food Science and Nutrition. 40: 1453-1459 (2011)

Kalman D. Amino acid composition of an organic brown rice protein concentrate and isolate compared to soy and whey concentrates and isolates. Foods, 3: 394-402 (2014)

Kim YS. Quality of wet noodle prepared with wheat flour and mushroom powder. Korean Journal of Food Science and Technology. 30: 1373-1380 (1998)

Kim S. Sources and formulation of macro-and micro-nutrients in enteral nutrition formula. Journal of Clinical Nutrition. 8: 45-50 (2016)

Kim YA. Soy protein: a high-quality, plant-based protein. Food Science and Industry 51(4) : 270-277 (2018)

Kim GS, Park GS. Quality characteristics of cookies prepared with lotus leaf powder. Korean Journal of Food and Cookery Science. 24: 398-404 (2008)

Kreger JW, Lee Y, Lee SY. Perceptual changes and drivers of liking in high protein extruded snacks. Journal of Food Science. 77: S161-S169 (2012)

Layman DK, Baum JI. Dietary protein impact on glycemic control during weight loss. The Journal of Nutrition. 134: 968S-973S (2004)

Lazo O, Claret A, Guerrero L. A comparison of two methods for generating descriptive attributes with trained assessors: Check-all-that-apply (CATA) vs. free choice profiling (FCP). Journal of Sensory Studies. 31: 163-176 (2016)

Lee JY, Ju JC, Park HJ, Heu ES, Choi SY, Shin JH. Quality characteristics of cookies with bamboo leaves powder. The Korean Journal of Food And Nutrition. 19(1): 1-7 (2006)

Lim EJ, Huh CO, Kwon SH, Yi BS, Cho KR, Shin SG, Kim SY, Kim JY. Physical and sensory characteristics of cookies with added leek (Allium tuberosum Rottler) powder. Korean J Food & Nutr. 22(1): 1-7 (2009)

Martin AH, Castellani O, de Jong GA, Bovetto L, Schmitt C. Comparison of the functional properties of RuBisCO protein isolate extracted from sugar beet leaves with commercial whey protein and soy protein isolates. Journal of the Science of Food and Agriculture. 99: 1568-1576 (2019)

Mendes RH, Hagen MEK, Barp J, Jong EVD, Moreira JD, Oliveira ÁRD, Irigoyen MCC, Belló-Klein A. Isolated soy protein-based diet ameliorates glycemia and antioxidants enzyme activities in streptozotocin-induced diabetes. Food and Nutrition Sciences. 5: 2089-2096 (2014)

Meyners M, Castura JC, Carr BT. Existing and new approaches for the analysis of CATA data. Food Quality and Preference. 30: 309-319 (2013)

Ministry of food and drug safety [Internet]. Food labeling standards, 2019 [cited 2019 October 29] Available from: https://www.mfds.go.kr/brd/m_211/view.do?seq=14378

Moon YJ, Jang SA (2011). Quality characteristics off cookies containing powder of extracts from Angelica gigas Nakai. The Korean Journal of Food And Nutrition. 24(2):173-179.

Park BH, Cho HS, Park SY. A study on the antioxidative effect and quality characteristics of cookies made with Lycii fructus powder. Korean Journal of Food and Cookery Science. 21: 94-102 (2005)

Paul GL. The rationale for consuming protein blends in sports nutrition. Journal of the American College of Nutrition. 28: 464S-472S (2009)

Rababah TM, Al-Mahasneh MA, Ereifej KI. Effect of chickpea, broad bean, or isolated soy protein additions on the physicochemical and sensory properties of biscuits. Journal of Food Science. 71: S438-S442 (2006)

Russell TA, Drake MA, Gerard PD. Sensory properties of whey and soy proteins. Journal of Food Science. 71: S447-S455 (2006)

Singh M, Mohamed A. Influence of gluten–soy protein blends on the quality of reduced carbohydrates cookies. LWT. 40: 353-360 (2007)

Tuorila H, Lähteenmäki L, Pohjalainen L, Lotti L. Food neophobia among the Finns and related responses to familiar and unfamiliar foods. Food Quality and Preference. 12: 29-37 (2001)

Zoulias EI, Oreopoulou V, Tzia C. Effect of fat mimetics on physical, textural and sensory properties of cookies. International Journal of Food Properties. 3: 385-397 (2000)