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Evaluation of Wheat Noodles Supplemented with Soy Protein Isolate for Nutritional, Textural, Cooking Attributes and Glycemic Index

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Abstract: The elderly population in developed countries has increased rapidly in recent years; the elderly may be at greater risk of protein deficiency due to dietary, socio-economic, dental, and physical restrictions. Therefore, to address the issue of protein deficiency in elderly people, the present study aimed to enhance the protein content of high-gluten flour noodles, an Asian staple food, by supplementing them with soybean protein isolate (SPI) powder. The effect of SPI addition (5–20%, *w*/*w*) on composition, quality, texture, physical and sensory properties, and glycemic index (GI) of high-gluten flour noodles was investigated. The noodles made only from high-gluten flour served as control. In comparison to control noodles, 20% SPI noodles showed a rise in protein and moisture content from 16.17% to 30.64% and 36.06 to 44.84%, respectively. The cooking yield and cooking loss increased with an increase in SPI concentration compared to control noodles. Color characteristics analysis revealed the decreasing trend in brightness and yellowness of SPI noodles with minimal L* and b* values at a 20% SPI concentration. The addition of SPI also resulted in a decrease in the hardness and tensile strength of the noodles. The sensory analysis showed that 5% SPI noodles were more similar to control noodles in terms of flavor, taste, and overall acceptability. Moreover, the addition of SPI to the noodles significantly decreased the GI of the noodles reaching the standard of low-GI food. The findings of the current study indicate that soy protein noodles, besides supplementing the desired nutrients, may also prevent the risk of diabetes in elderly people.

Keywords: Asian noodles; wheat flour; soybean protein isolate; cooking properties; texture; nutrition

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1. Introduction

According to World Health Organization (WHO), by 2030, the world's population is expected to reach the super-aging stage, with 12.5% of the world's population aged 60 or older at present [1]. According to projections, there will be 1.5 billion people over the age of 65 in the world by 2050, an increase from 727 million in 2020 [2]. In Taiwan, approximately 24% of the population is expected to be aged 60 and above by 2030 [1]. Age-related anabolic resistance to the dietary amino-acid-induced protein synthesis in skeletal muscle results in a lack of protein for muscular growth. This may lead to sarcopenia, a condition marked by a progressive decline in muscle mass, strength, and function. Also, the aged population consumes insufficient amounts of proteins with important biological functions, which raises the possibility of a loss of muscle mass and may exacerbate sarcopenia [3,4]. As per recommendations from the European Society for Clinical Nutrition and Metabolism (ESPEN), a protein intake of 1.0–1.2 g/kg body weight per day is helpful in maintaining/increasing muscle mass and decreasing the risk of physical disability, which is higher than the recommended dietary allowance (R.D.A.) of 0.8 g/kg/d [2,5]. Additionally, the need for dietary proteins has increased due to changes in lifestyle and the growing human population. Past studies have also shown that older persons who consume the recommended amount of protein have reduced frailty risks and lean mass loss than those who consume less protein [6–8]. The recommended daily protein intake for the elderly, however, is a hard target to attain, increasing the risk of protein malnutrition. The insufficient consumption of protein in the older population can be attributed to multiple reasons, mainly including reduced energy requirement, physical dependence for buying and preparing food, anorexia due to aging or medical conditions, neurosensorial changes in food preference, poor dentition, and food insecurity owing to monetary and social limitations [9]. On the other hand, vegetarians may experience protein deficiency and insufficient intake of essential amino acids in the long run because of their dietary restrictions. The protein intake in the elderly population can be increased by supplementing the regularly eaten food with a high amount of protein such as noodles, which is one of the staple foods in many Asian countries [10,11].

Noodles are usually made from wheat flour, which makes them rich in carbohydrates but deficient in proteins [12]. Some additives have been used in the noodle-making process to enhance the nutritional value of noodles. Rani et al. used a mixture of refined wheat flour, soy flour, and sorghum flour to make multigrain noodles, and the noodles were found to have enhanced nutritional and antioxidant properties [12]. Li et al. mixed heat moisture treatment corn starch, high-amylose corn starch, or green banana flour with wheat flour to make a low-GI noodle, and the noodles showed good acceptability [13]. Wheat flour can be fortified with protein to increase the protein content in the noodles and meet the overall protein requirements of the elderly population. Soy protein is an ideal supplement for wheat flour owing to its excellent nutritional content, positive effects on calcium metabolism, and ability to decrease cholesterol [14,15]. Various soy products have been reported to fortify wheat flour, viz., soy protein [14], soy milk [16], soy protein hydrolysate [17], etc. Soy protein may improve cognitive function in the elderly [18] and has been found to improve glycemic control and decrease HbA1c compared to casein [19].

Soybean protein isolate (SPI) is extracted from soybeans after the removal of the majority of fat and carbohydrates, resulting in high protein content. SPI contains a well-balanced amino acid composition, is an important protein resource and an excellent food additive. SPI has not only high nutritional value but also many other functions such as emulsification, water absorption, oil absorption, gelation, adhesion and dispersion, and therefore has immense potential to be widely used in the food industry [20]. SPI can be utilized as a food additive in the making of meat products [21], dairy products [22], flour products [23], beverages and health products [24]. Returning to the subject, noodles supplemented with SPI can be used as a protein-fortified food for the elderly. Other ethnic groups including diabetics and obese people, may also benefit from this as soy protein may help lower the risk of diabetes and improve glycemic control [25]. Noodles supplemented with protein do not only taste like ordinary noodles but also complement nutrition and fulfill personal needs [26].

Many foods have been fortified with soy protein [12,27], but there is a paucity of research on the effects of adding soy protein isolate (SPI) on the nutritional and textural qualities as well as the glycemic index (GI) of high-gluten flour noodles. Therefore, in this study, SPI was added to noodles to investigate the effect of soybean protein isolate on the taste as well as chemical, physical and textural properties of the noodles. High-gluten flour was used as the base to make SPI noodles, and SPI noodles were prepared by adding different proportions (5–20%) of SPI to compare with the noodles prepared from only high-gluten flour (control). The cooked noodles were evaluated for cooking yield, cooking loss, moisture content, sensory properties, and glycemic index.

2. Materials and Methods

2.1. Materials

High-gluten wheat flour was provided by Uni-President Enterprises Corp. (Tainan, Taiwan). The moisture, crude protein, carbohydrate, and fat of wheat flour were 13.2%, 13.5%, 71.5%, and 1.68%, respectively. The soy protein isolate powder was purchased from Less Plus One International Enterprise Co., Ltd. (New Taipei, Taiwan).

2.2. Preparation of Noodles

For test sample preparation, high-gluten wheat flour was mixed with 5 g, 10 g, 15 g, and 20 g of SPI powder to make a total solid weight of 100 g resulting in a final SPI concentration of 5%, 10%, 15% and 20% (w/w). The control group contained 100 g of high-gluten flour. The test and control flour samples mixed with 50 mL of water were then separately put into a noodle maker (TB-8102, Heas Technology, Corp., New Taipei City, Taiwan) and stirred for 13 min to make dough. Afterwards, the dough was extruded from a cylindrical nozzle to obtain the desired noodle strands with a thickness of 2 mm and a width of 5 mm.

2.3. Quality Analysis

2.3.1. Proximate Analysis

Crude protein, fat, and ash contents were determined according to the AOAC methods [28]. The moisture content of raw noodles was estimated using a halogen moisture analyzer (SH10A, Shanghai Jinghai Instrument Co., Ltd., Shanghai, China).

2.3.2. Cooking Yield

The cooking yield of the noodles was determined according to the method of Sim et al. [29] with some minor modifications. During the cooking process, 20 g of noodles were boiled for 4 min in 200 mL of water, then rinsed twice with 300 mL of water (25 °C) for 10 s. Noodles were placed in a noodle strainer, then tapped forcefully on the edge of a sink 10 times to drain excess water. The weight of the cooked noodles was measured, and the cooking yield was calculated based on the ratio of cooked-noodle weight to raw-noodle weight.

2.3.3. Cooking Loss

The cooking loss of noodles was determined using a modified method of Sim et al. [29]. About 5 mL of cooking water was taken in a test tube and dried in an oven at 105 °C for 24 h. The residue was weighed and proportionately scaled to the total volume of the cooking water. Cooking loss was reported as the percentage of the total weight of residues in the cooking water to the total weight of noodles before cooking.

2.4. Color Measurement

The color values of test and control noodles were estimated using a colorimeter (SA2000, Nippon Denshoku Industries Co., Ltd., Tokyo, Japan) based on L*, a*, b* parameters. The L*, a*, b* values represent scale ranges from black to white (0–100), negative green to a positive red and negative blue to positive a yellow value, respectively.

2.5. Evaluation of Texture and Sensory Properties of Cooked Noodles

Texture analysis is the main evaluation method for noodles [30]. Texture analyzer can measure the hardness, cohesiveness, springiness, gumminess, chewiness, and adhesiveness of the sample in the measurement mode. The physical properties, viz., tension, hardness, cohesion, elasticity, chewiness, stickiness and adhesiveness of noodles were assessed using a texture analyzer (Brookfield CT3 Texture Analyzer, Brook-field Engineering Laboratories, Middleboro, MA, USA). Firstly, the noodles were boiled in boiling water for 4 min. Subsequently, the noodle strands of final length of 5 cm were taken out and fixed on a TA-RT-KIT fixture. The tension, hardness, cohesion, elasticity, chewiness, stickiness and adhesiveness of the noodles were measured using a hook-shaped TA-KF probe. The parameters set for texture profile analysis (TPA) were as follows: test speed of 0.5 mm/s; distance of 1.33 mm; load of 0.067 N; adjustment measurement of 14 mm. The physical characteristic results were derived from the texture profile and force–time curve produced by the instrument software and expressed digitally. Three individual noodles were taken from each group for testing.

The control and 20% SPI noodles were also subjected to IDDSI (International Dysphagia Diet Standardisation Initiative) testing in order to categorize the texture of the noodles for the aged population [31]. The noodles were subjected to a fork pressure test, fork drip test and a spoon tilt test as per Level 5 food testing of IDDSI since the noodles showed the characteristics of Level 5 food such as the possibility of being eaten with a fork or spoon, scooped and shaped and being soft and moist with no separate thin liquid. For the fork pressure test, the thumb finger was used to apply pressure to the noodle samples using a fork until the thumbnail blanched. The pressure applied was ~17 kPa which is equivalent to the pressure of the tongue while swallowing. The fork drip test was carried out by picking the noodles with a fork to examine the shape of the noodles on the fork and the flow behavior through the fork prong. The spoon tilt test was carried out by scooping the noodles with a spoon and slowly tilting the spoon sideways to evaluate the adhesiveness and cohesiveness of the samples.

Sensory analysis of the cooked noodles was performed by 30 panelists (10 males and 20 females) who were university students/employees at the Department of Seafood Science aged between 20 and 40 years. The cooked noodles were put into uniform plastic cups and covered; then, they were presented following a design balanced for presentation order (William Latin square) to the panelists. The noodles were evaluated for flavor, taste and overall acceptability. A nine-point liking scoring method was used to measure the acceptability of the noodles, where 1 represents "extremely dislike" and 9 represents "extremely like".

2.6. Glycemic Index Determination

The GI determination was carried out via in vivo experiments. Since one of the main aims of the study was to increase the protein content of the noodles and study the correlation between high protein content and GI, only 20% SPI noodles were used for the estimation of the glycemic index. Three subjects aged between 20 and 24 years were chosen for assessment, and their fasting glycemic index was measured. During the study period, the subjects did not take any medications and avoided smoking and physical activity. The subjects were given either 50 g of glucose as a standard or noodles containing 50 g carbohydrates, along with 150 mL water, to consume within 15 min. Blood sugar was recorded 15, 30, 45, 60, 90 and 120 min after consumption by using blood glucose machine (Taibo Technology Co., Ltd. Wugu Factory, Taiwan). A graph of the blood-glucose-concentration–time relationship was established and the GI value was calculated using the equation below. A total of 50 g of glucose was used as a reference food.

$$\text{Glycemic index } (\%) = \frac{\text{area under the blood sugar curve of the sample}}{\text{area under the blood sugar curve of the reference food}} \times 100. \quad (1)$$

2.7. Statistical Analysis

An analysis of experimental data using one-way analysis of variance (AVOVA) was conducted with JMP software (SAS Institute Inc., Cary, NC, USA). The Tukey–Kramer HSD test was applied to compare the means for all pairs, and the least significant difference (LSD) test was used to compare the means among different groups. Differences in the results were considered statistically significant at p-values < 0.05.

3. Results and Discussion

3.1. Proximate Composition

The proximate composition of SPI flour, control noodles and SPI noodles is shown in Table 1. The SPI powder was rich in protein (78.54%), while the carbohydrate, lipid and ash contents were only 3.24%, 0.27% and 4.59%, respectively. Control noodles and noodles supplemented with 5%, 10%, 15% and 20% SPI were analyzed for their proximate compositions. The protein content of control noodles was 16.17%, while carbohydrates were the main components and accounted for 47.05% in the noodles. In contrast, 20% SPI noodles were mainly composed of protein with a 30.69% protein content, which was higher than the carbohydrate content of 23.06%. Therefore, the protein content of 20% in SPI noodles had a significant increase of about 1.89-fold compared to control noodles. Additionally, the ash content exhibited an upward trend, while there was no significant difference observed in the lipid content. The result indicated that the addition of SPI to the high-gluten flour contributed to the increase in the crude protein content of the noodles. The high digestibility of soy protein also makes it a promising protein source, especially for the vegetarian population, compared to other proteins. Protein digestibility refers to the percentage of ingested amino acids that may be used by the body after digestion and absorption. About 95–98% digestibility has been reported for soy protein with a Protein Digestibility Corrected Amino Acid Score of 0.92–1.00, which is comparable with animal protein (milk, egg, beef and whey) [32,33]. Similar findings were also observed in pasta made with sunflower meal protein isolate or with high-protein raw materials [34,35]. The protein content of the pasta supplemented with a 9% sunflower meal protein isolate was enhanced to 19.33% compared to the control pasta (11.00%) while the carbohydrate content decreased from 80.73% to 71.43% [34]. In addition, noodles with sorghum flour and soybean flour [12] or with lentil, pea, and faba bean hulls [36] were also shown to have a higher ash content. High ash content indicates that SPI noodles contain higher levels of minerals and vitamins.

Table 1. Proximate composition of SPI powder, noodles and SPI noodles.

Sample	Moisture (%)	Crude Protein (%)	Lipid (%)	Ash (%)	Carbohydrate (%)
SPI powder	13.39 ± 0.01^{d}	78.54 ± 1.45^{a}	0.27 ± 0.04^{a}	4.59 ± 0.04^{a}	3.24 ± 1.45^{f}
Noodles (control)	36.06 ± 0.02^{c}	16.17 ± 0.46^{f}	0.31 ± 0.07^{a}	0.43 ± 0.06^{e}	47.05 ± 2.43^{a}
5% SPI noodles	37.67 ± 0.00^{bc}	19.83 ± 0.82^{e}	0.30 ± 0.01^{a}	0.90 ± 0.00^{d}	41.05 ± 1.05^{b}
10% SPI noodles	39.18 ± 0.01^{b}	23.17 ± 0.41^{d}	0.26 ± 0.06^{a}	1.07 ± 0.01^{d}	35.97 ± 0.04^{c}
15% SPI noodles	43.36 ± 0.01^{a}	27.06 ± 0.83^{c}	0.28 ± 0.04^{a}	1.28 ± 0.04^{c}	27.52 ± 0.65^{d}
20% SPI noodles	44.84 ± 0.01^{a}	30.69 ± 0.32^{b}	0.26 ± 0.04^{a}	1.50 ± 0.18^{b}	23.06 ± 0.80^{e}

The Tukey–Kramer HSD test was applied to compare means for all pairs. Data are expressed as mean ± SD (n = 3). Means followed by different letters are significantly different at $p < 0.05$.

3.2. Cooking Properties

The incorporation of various amounts of SPI into high-gluten wheat flour noodles significantly changed the cooking properties (Table 2). The moisture of raw noodles increased with the increasing replacement rate of SPI. Increasing the SPI content to 10% caused a significant difference in the moisture content of SPI noodles and control noodles. Mohajan et al. found that the incorporation of soy flour into soup powder increased the water absorption capacity of the soup powder [37]. SPI has high water-holding capacity, water retention, and expansion, and is therefore widely used in the food industry as a gelling agent [38]. The high water-absorption capability of SPI noodles might be due to their high protein content, which encourages the formation of hydrogen bonds between the water molecules and the polar groups on the polypeptide chains. Therefore, the moisture content of raw noodles increased with the increase in SPI content due to the water absorption of SPI during cooking. Similar to our results, an increase in moisture content was reported for SPI-supplemented whole-grain flat rice noodles (64.98%) compared to control noodles (59.78%) [39].

Table 2. Effects of SPI proportions on moisture content, cooking loss, and cooking yield of SPI noodles.

Sample	Moisture of Raw Noodles (%)	Cooking Yield (%)	Cooking Loss (%)
Noodles	36.06 ± 0.01 ^{c}	1.42 ± 0.01 ^{c}	0.82 ± 0.03 ^{c}
5% SPI noodles	37.67 ± 0.02 ^{bc}	1.45 ± 0.03 ^{bc}	0.89 ± 0.32 ^{c}
10% SPI noodles	39.18 ± 0.01 ^{b}	1.50 ± 0.02 ^{b}	1.25 ± 0.24 ^{b}
15% SPI noodles	43.36 ± 0.01 ^{a}	1.52 ± 0.02 ^{b}	1.44 ± 0.15 ^{ab}
20% SPI noodles	44.84 ± 0.02 ^{a}	1.65 ± 0.07 ^{a}	1.61 ± 0.20 ^{a}

The Tukey–Kramer HSD test was applied to compare means for all pairs. Data are expressed as mean ± SD (n = 3). Means followed by different letters are significantly different at $p < 0.05$.

The cooking yield of noodles is listed in Table 2. The cooking yield is an important indicator of noodle quality, which is mainly contributed by starch gelatinization and water absorption by protein. The cooking yield of 5%, 10%, 15%, and 20% SPI noodles was 1.45, 1.50, 1.52, and 1.65%, respectively. A higher SPI content resulted in a higher cooking yield compared to control noodles. Since SPI had high water-holding ability, the cooking yield of SPI noodles increased during cooking indicating a positive correlation between water absorption and cooking yield in this case [29,40]. This is because of the presence of many polar groups on the backbone of SPI, resulting in water retention and swelling of the noodles. The water absorption of wheat flour spaghetti has been reported to increase significantly as the gluten level increased [41]. On the other hand, the cooking loss of 5%, 10%, 15%, and 20% SPI noodles was 0.89, 1.25, 1.44, and 1.61%, respectively. The SPI noodles showed higher cooking loss than the control noodles. Gluten protein is responsible for maintaining the structural integrity of noodles [42]. During the cooking of noodles, the gluten network structure can prevent the carbohydrate from leaching into the water. Reduced gluten leads to a weaker structure, which allows more noodle content to dissolve into the cooking water, thus increasing cooking loss [40,43]. The results of the present study were in line with those of other reported studies. An addition of cassava pulp (1–20%) and pomelo peel (5–10%) to rice noodles resulted in increased cooking loss with an increase in the amount of either cassava pulp and pomelo peel compared to control rice noodles [44]. A study reported the supplementation of durum semolina flour with α-galactoside-free sweet lupin flours (*Lupinus angustifolius* var. Emir and *Lupinus angustifolius* var. Troll) aiming to produce flatulent oligosaccharide-free pasta with high nutritional value. It was observed that with the increase in the concentration of Emir and Troll flour, the cooking loss increased and was maximum at 100 g/kg of lupin pasta [43].

3.3. Color Characteristics of the Raw Noodles

The color of the noodles was determined using a spectrophotometer (SA2000, Nippon Denshoku Industries Co., Ltd., Tokyo, Japan). The color measurement of SPI noodles made by adding different levels of SPI is presented in Table 3. As the amount of SPI increased, the L*, a*, and b* values were found to change from 71.34 to 67.93, 3.82 to 4.42, and 1.46 to 0.67, respectively. The L* value, which represents brightness, showed a decreasing trend with increasing SPI levels. According to the findings of Oh et al., the color of dry noodles darkened as protein content increased [45]. Guo et al. reported that the addition of soy protein hydrolysates to flour reduced the brightness of the noodles [40]. Increasing the SPI content resulted in an increase in protein content, whereas decreasing the starch fraction led to changes in the reflectivity of light. Although the a* value (redness–greenness) increased with the increase in the SPI content from 3.82 to 4.42, the statistical results showed no significant difference. In contrast, the b* value (yellowness–blueness) decreased as SPI levels increased. Soybean flour and SPI contain lipoxygenase [46]. This may be due to the interaction between the lipoxygenase in SPI and the carotene in flour, which lowers the amount of carotene and therefore reduces the b value.

Table 3. Color Characteristics of the Raw Noodles.

Sample	L*	a*	b*
Noodles	71.34 ± 0.39 [a]	3.82 ± 0.36 [a]	1.46 ± 0.50 [a]
5% SPI noodles	70.19 ± 0.32 [ab]	4.08 ± 0.37 [a]	1.18 ± 0.13 [ab]
10% SPI noodles	68.66 ± 0.82 [bc]	4.36 ± 0.39 [a]	1.16 ± 0.28 [ab]
15% SPI noodles	68.91 ± 1.28 [bc]	4.46 ± 0.47 [a]	0.86 ± 0.13 [b]
20% SPI noodles	67.93 ± 2.21 [c]	4.42 ± 0.36 [a]	0.67 ± 0.30 [b]

The Tukey–Kramer HSD test was applied to compare means for all pairs. Data are expressed as mean ± SD (n = 3). Means followed by different letters are significantly different at $p < 0.05$.

3.4. Texture Properties and Sensory Evaluation

The textural properties of cooked noodles depend on many factors, including flour quality, water absorption, ingredients processing parameters, etc. The texture analysis results of cooked SPI noodles are shown in Table 4. As SPI content increased, hardness, cohesiveness, tensile strength, adhesiveness, springiness, gumminess and chewiness showed a significant downward trend. Yadav et al. reported a negative correlation between the hardness of noodles and their water absorption capacity [47]. As shown in Table 1, the addition of SPI to noodles led to higher moisture content. This suggests that incorporating more SPI enhances water absorption capacity while also causing a decrease in the hardness of noodles. A whole-grain flat rice noodle containing SPI has been reported to have reduced hardness and chewiness due to SPI's high water-holding capacity [39]. Tensile strength measures the amount of force required to break a noodle of a fixed length under a specific speed and force. A higher tensile strength indicates greater gluten strength in the noodle. The findings in Table 4 demonstrate a negative correlation between tensile strength and the addition of SPI to the noodle. This result is consistent with that of Detchewa et al. who found that a higher SPI content in gluten-free rice spaghetti led to a lower tensile strength [48]. As the proportion of SPI increased, the gluten strength of the noodles decreased, which affected noodle texture in terms of cohesiveness, springiness, gumminess, chewiness, and adhesiveness, ultimately impacting overall taste. Moreover, the IDDSI test results showed that both control and 20% SPI noodles were easily deformed and squashed by the fork, did not fall from the fork and also did not stick to the spoon (Figure S1). The results confirmed that the samples passed all three tests, i.e., the fork pressure test, fork drip test and the spoon tilt test, and were categorized as Level 5 minced and moist food as per IDDSI. Although the IDDSI framework is an easy-to-use and efficient testing technique to identify texture-modified foods, due to the subjective judgment with visual inspection, this method has some drawbacks.

To evaluate the sensory qualities of the noodles, different proportions of SPI were used. The result presented in Table 5 showed that the control noodles (0% SPI) obtained the highest flavor, taste, and overall acceptability scores of 6.30, 7.01 and 6.97, respectively. However, the sensory evaluation scores showed that the flavor, texture, and overall preference of noodles with a 5% SPI were very similar to those of the control group, with no statistically significant differences observed. These results suggest that noodles fortified with 5% SPI are acceptable to consumers. In contrast, the scores for noodles with a 10%, 15%, and 20% SPI were lower, likely due to the increasing softness of the texture and the stronger soy flavor, which might result in an unpleasant taste. In practical application, protein-enriched noodles are essential for maintaining good health. The texture analysis and evaluation results indicate that noodles fortified with SPI have a softer texture and therefore might be more suitable for elderly individuals with poor oral and dental function.

Table 4. Texture properties of noodles with different proportions of SPI.

Sample	Hardness (g)	Cohesiveness	Tensile Strength (g)	Adhesiveness (mJ)	Springiness (mm)	Gumminess (g)	Chewiness (mJ)
Noodles	30.17 ± 1.15 [a]	0.88 ± 0.14 [a]	82.67 ± 6.05 [a]	0.17 ± 0.03 [a]	7.62 ± 0.30 [a]	13.4 ± 0.99 [a]	0.58 ± 0.19 [a]
5% SPI noodles	26.5 ± 1.41 [b]	0.54 ± 0.10 [ab]	71.33 ± 5.97 [b]	0.16 ± 0.08 [a]	7.25 ± 0.30 [a]	10.15 ± 0.21 [a]	0.53 ± 0.11 [a]
10% SPI noodles	24.5 ± 0.00 [b]	0.52 ± 0.32 [ab]	55.33 ± 1.61 [c]	0.09 ± 0.03 [b]	7.02 ± 1.49 [a]	10.83 ± 6.11 [a]	0.27 ± 0.09 [b]
15% SPI noodles	20.5 ± 2.78 [c]	0.51 ± 0.15 [b]	40.83 ± 1.04 [d]	0.08 ± 0.02 [b]	6.89 ± 0.09 [a]	9.83 ± 2.22 [a]	0.20 ± 0.01 [b]
20% SPI noodles	19.83 ± 1.26 [c]	0.48 ± 0.03 [b]	37.00 ± 2.18 [d]	0.06 ± 0.04 [b]	4.54 ± 0.39 [b]	10.2 ± 0.85 [a]	0.09 ± 0.01 [b]

The Tukey–Kramer HSD test was applied to compare means for all pairs. Data are expressed as mean ± SD (n = 3). Means followed by different letters are significantly different at $p < 0.05$.

Table 5. Sensory evaluation of noodles with different proportion of SPI.

Sample	Flavor	Taste	Overall Acceptability
Noodles (control)	6.30 ± 1.12 [a]	7.01 ± 0.91 [a]	6.97 ± 0.93 [a]
5% SPI noodles	5.90 ± 1.35 [ab]	6.37 ± 1.27 [a]	6.37 ± 1.22 [a]
10% SPI noodles	5.34 ± 1.42 [bc]	5.31 ± 1.44 [b]	5.38 ± 1.57 [b]
15% SPI noodles	5.00 ± 1.44 [c]	4.17 ± 1.68 [c]	4.70 ± 1.68 [bc]
20% SPI noodles	4.67 ± 1.65 [c]	3.73 ± 1.76 [c]	4.23 ± 1.85 [c]

The Tukey–Kramer HSD test was applied to compare means for all pairs. Data are expressed as mean ± SD (n = 30). Means followed by different letters are significantly different at $p < 0.05$.

3.5. Glycemic Index of SPI Noodles

Low-glycemic-index foods have been shown to elicit hypoglycemic and normal insulin responses, improving blood sugar control in individuals with type 2 diabetes. To test the GI of noodles fortified with 20% SPI versus control noodles, a blood sugar test of three subjects aged 20–24 years with BMI (body mass index) ranging from about 19 to about 25.7 was conducted after the subjects ate noodles. Figure 1 displays glucose level changes in blood sugar with time. The control noodles resulted in a maximum blood sugar level of 126 mg/dl after 0.5 h of eating noodles, whereas the blood glucose peak of 20% SPI noodles was relatively flat, indicating a slower rise in blood glucose, with a maximum value of 106 mg/dL at 0.5 h, showing a significant difference. After calculating the GI value using Equation (1), the control noodles had a high GI value of 74.12, while for 20% SPI noodles, the GI value decreased significantly to 48.63. Typically, foods with a GI value of 70 or above are considered to have a high GI, while a medium GI ranges from 56 to 69, and a low GI has a value of 55 or less [49,50]. Therefore, the GI value of 20% SPI noodles falls within the low-GI food category. Soybean has also been reported to lower GI and aids in maintaining blood glucose levels in patients suffering from diabetes mellitus. This could be due to the inhibitory effect of protein on carbohydrate digestibility as protein covers the surface of starch granules, absorbs water, prevents water from moving into the core of the granules, and limits the expansion of the granules after heating. Moreover, the protein covering might also lower the accessibility of carbohydrates to hydrolytic enzymes, thereby reducing their digestibility and ultimately lowering GI [26]. The most common system for ranking foods is the GI, which is a relative ranking of carbohydrates in foods in comparison to a reference food and which measures the ways in which it affects blood glucose response [51]. Low-GI foods are digested, absorbed, and metabolized slowly, resulting in a lower and more gradual increase in blood sugar levels, thereby reducing the need for insulin [52]. Rani et al. reported an increase in protein content and a decrease in GI for multigrain noodles (refined wheat flour (62.2%), sorghum flour (24.6%), soy flour

(13.2%) and gluten (2.95%)) compared to control noodles made from only refined wheat flour. In the case of multigrain noodles, the protein content was increased to 17% from 13%, whereas GI was decreased to 31 from 40 compared to control noodles [12]. In another study, fortification of gluten-free sweet potato flour spaghetti was attempted using whey protein concentrate (WPC) and chickpea flour (CPF) with an aim to increase the protein content and decrease the glycemic index. The results revealed that the protein content was increased by 192.20% and 150.08% for spaghetti fortified with WPC and CPF, respectively, compared to the control. The decrease in glycemic index was also observed with 15% CPF (59.43) and 15% WPC (58.73) in comparison to control (63.92) [53]. Similarly, increased protein content (14.5%) and decreased average glycemic index (39.19) were observed for wheat flour bread fortified with 20% soy flour [54]. Comparison with other reported studies indicated that the results of the present study were in line with those in the literature. A decrease in GI may aid in blood sugar stabilization, lower the risk of diabetes, high blood pressure, and cardiovascular disease, and boost high-density lipoprotein levels. Healthier foods with a low GI and high protein content are suitable for various groups such as diabetic and obese elderly patients.

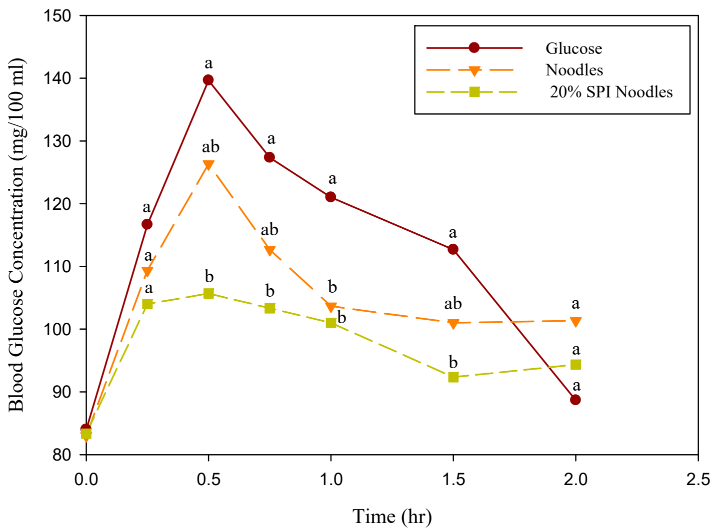

Figure 1. Blood glucose response curve of glucose, noodles, and 20% SPI noodles. According to the LSD (least significant difference) test, means followed by different letters at the same time are significantly different at $p < 0.05$.

4. Conclusions

The present study explores the detailed impact of adding soybean protein isolate to high-gluten flour noodles. The addition of a 20% SPI enhanced the protein (30.69%) and moisture content (44.84%) of the noodles and reduced the carbohydrate content (23.06%). This increase in protein content may make noodles suitable for elderly people who are generally more susceptible to protein deficiency. The addition of SPI also altered the textural and sensory properties of the noodles. The control noodles were more acceptable in terms of flavor and taste. However, no statistically significant difference was observed between 5% SPI noodles and control noodles indicating that 5% SPI noodles were similar to control noodles in taste, flavor and overall acceptability. The addition of SPI not only increased the protein content of the noodles, but also categorized the noodles into the low-GI food with a GI of 48.63 for 20% SPI noodles. Synergistic risk factors such as hypertension and obesity are frequently present in people with diabetes, and they raise the risk of cardiovascular disease death rates. High GI is associated with an increased risk of cardiovascular disease events, and hence regulation of GI in patients with type 2 diabetes plays a crucial role; such regulation may also aid in lowering the risk of cardiovascular diseases. Considering the association of GI with diabetes and cardiovascular disease, the findings of the present study may serve as an impetus for regulating these factors in elderly people with the addition of SPI in noodles. Further, the quality of soy protein can also be improved by removing the anti-nutritional compounds and by breaking the protein into smaller peptides. Although soy protein has been proven to be beneficial in various aspects, further investigation on the soy-protein-related allergies is needed. Moreover, an in-depth study is required to achieve better insights about the interactions between protein and components of different foods apart from noodles to produce various protein-rich foods without compromising the food quality in order to satisfy consumer expectations.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/app13137772/s1, Figure S1: IDDSI (International Dysphagia Diet Standardization Initiative, 2019) tests on control and 20% SPI noodles.

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