Heliyon 10 (2024) e35810

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Alternative protein sources from selected legumes and mushrooms in the development of high-protein instant soup for the elderly

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ARTICLE INFO

Keywords:
Alternative protein
Instant soup
Elderly
Physicochemical properties
Nutritional qualities

ABSTRACT

Elderly people are susceptible to malnutrition due to many factors. An essential public health priority is ensuring that seniors have appropriate nutrition to prevent and treat malnutrition and dehydration as well as fulfilling the nutrition necessity. This study was conducted to utilize selected legumes and mushrooms to develop a high-protein instant soup (HPIS) product that is nutritious and suitable for the consumption of the elderly. Black bean, along with oyster mushroom and split-gill mushrooms, exhibited considerable amounts of protein (19.13 ± 1.13, 2.77 ± 0.09, and 4.65 ± 0.61 g/100 g, respectively), calcium (2308.65 ± 113.07, 640.19 ± 0.80, and 743.89 ± 0.66, respectively), iron (40.84 ± 2.42, 7.31 ± 0.05, and 40.10 ± 2.15, respectively), and zinc (18.06 ± 1.07, 3.87 ± 0.03, and 26.23 ± 0.78, respectively) content, and were incorporated into the HPIS formula. Drum dryer rotation speed significantly affected the HPIS properties. The study on the effect of different rotation speeds (3, 5, 7, and 9 RPM) used during the drying process revealed the use of 7 RPM resulting in the soup product with considerable quality. The optimized HPIS formula, which was supplemented with minerals, was moderately liked (7.1–7.5) by the elderly consumer. The majority of the consumers accepted the product (97 %) and were interested in purchasing the product (91 %) if it was available on the market. Incorporating selected legumes and mushrooms resulted in a soup product containing nutrition conforming to the Thai recommended daily intake (RDI), possessing adequate physicochemical and sensory properties for the consumption of the elderly.

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https://doi.org/10.1016/j.heliyon.2024.e35810
Received 29 September 2023; Received in revised form 30 July 2024; Accepted 5 August 2024
Available online 5 August 2024

1. Introduction

The rapid change in the demographic makeup has led to an increase in the number of people over 60 and their fraction of the total population, whereas the number of children is continuing to fall. According to reports, there will be 1963 million elderly people worldwide by the year 2050, or 22 % of the global population, and by 2050, there are projected to be 22 million (or 27 % of the population) elderly in Thailand [1–4]. However, various issues will arise and are inevitable due to the increased population of the elderly, with one of them being nutritional issue.

Nutritional issues are common, especially in older people and in cases of acute and chronic sickness, and when combined with the symptoms of catabolic disease, a reduced dietary intake quickly results in malnutrition. Malnutrition is linked to poor outcomes, including a higher risk of mortality and longer hospital stays, convalescence times, and infection rates [5,6]. In addition to malnutrition, elderly people are more likely to get dehydrated for a variety of reasons, which can have major health repercussions [7,8]. On the other hand, obesity, with its well-known adverse health effects, is a growing issue in older adults as well, impacting between 18 and 30 % of the elderly population at present in the world [9,10]. To prevent and treat obesity as well as malnutrition and dehydration, providing proper nutrition, including sufficient amounts of food and liquid, is a major public health problem.

Protein is essential to humans and is thought of as the foundation of life. Dietary protein is necessary for cell repair and cell synthesis [11]. Growing data from experimental and epidemiological studies points to the possibility that older adults may require larger protein intakes than younger adults for the best maintenance of lean body mass, bodily processes, and health. For healthy elderly people, daily dosages of 1.0–1.2 g/kg body weight of protein have been recommended by numerous expert bodies, even higher when afflicted by illnesses, e.g., due to inflammation, infections, and wounds [12].

Vegetable-based soups are a wonderful alternative in terms of nutrition because they have a high nutrient density while being low in energy. Prior research suggested that eating more veggies may reduce the risk of developing some cancers, chronic respiratory disorders, obesity, cardiovascular diseases, and diabetes [13]. In its powder form, it has the advantage of protection from enzymatic and oxidative spoilage and flavor stability at room temperature over long periods (6–12 months). In addition, they are ready for reconstitution in a short time for working families, hotels, hospitals, restaurants, and institutional use as well as for military rations. Moreover, they exert lightweight for shipping and availability at all times of the year [13,14]. However, most of the locally available soups are not up to the mark regarding nutritional quality. The nutritional quality could be improved by introducing protein, minerals, and vitamin sources from plant origin that are suitable for all types of people. By including plant-based sources of protein, minerals, and vitamins, like legumes and mushrooms, which are good for vegetarians and others, the nutritional value of vegetable soup could be increased [14].

Beans, a type of legume, are high in nutrients whose advantages to health have been thoroughly investigated. While being low in total fat, saturated and *trans*-fat, salt, and cholesterol, beans are also high in protein, complex carbohydrates, dietary fiber, and micronutrients [15–17]. Due to their high nutrient density, beans can increase nutrient absorption through diet and lower the chance of acquiring chronic illnesses including diabetes, cancer, and cardiovascular disease, all of which are more likely to affect older persons [17–19]. Mushrooms are a low-calorie, high-fiber, vitamin, and mineral source. They are abundant in certain bioactive substances including the antioxidants ergothioneine and glutathione, which guard against cellular oxidative stress, and healthy carbohydrates like chitin and β-glucans, which are associated with fiber [20]. A lower risk of chronic diseases, such as several malignancies, depression, metabolic syndromes, cognitive decline, and dementia, is linked to mushroom consumption [21–24].

Providing nutrient-rich, simple-to-eat, and cooked foods, such as instant soup powder, is one way to prevent malnutrition and address the swallowing issue in elderly people [14]. Some research has been conducted on developing instant soup products to help address these issues. A healthy vegetable soup consisting of soy flour, mushroom, and moringa leaf was formulated by the study by Farzana et al. [14]. Another researcher also developed a pumpkin cream soup product with tempeh for the elderly [25]. However, the investigation on the formulation of instant soup products utilizing specific legumes and mushrooms intended for consumption by the elderly while considering the influence of the used drying method was yet to be done.

Developing an instant soup product from legumes and mushrooms might provide the required nutrition and prevent malnutrition issues among the elderly, while at the same time delivering an innovative food solution in combating malnutrition in the wider population. Thus, considering the background, this study was conducted to evaluate various formulations of an instant soup product utilizing specific legumes and mushrooms, along with its drying condition, in the development of a high-protein instant soup (HPIS) product supplemented with minerals following the Thai RDI that exhibited adequate physicochemical and sensory properties tailored for the nutritional requirements of the elderly.

2. Materials and methods

2.1. Raw materials

All the high protein instant food from legume and mushroom ingredients were purchased from Makro, Thailand: Mung bean protein powder (Yantai Protein Tech Co., Ltd.), red kidney beans (*Phaseolus vulgaris* L.) (Thanya Farm Co., Ltd.), black beans (*Phaseolus vulgaris*) (Thanya Farm Co., Ltd.), split-gill mushrooms (*Schizophyllum commune*) (BanHedkrang, Amphoe Chana, Songkhla, Thailand), straw mushrooms (*Volvariella volvacea*) (Siammakro Co., Ltd.), oyster mushrooms (*Pleurotus ostreatus*) (Siammakro Co., Ltd.), Hommali Rice (Tra Chat, Phayao, Thailand), and salt (Thai Refined salt Co., Ltd). All high-protein instant food from legume and mushroom samples were prepared in the pilot plant at the Faculty of Agro-Industry, Chiang Mai University, Thailand.

2.2. Proximate and mineral compositions of selected legumes and mushrooms

The selected legumes (red kidney and black beans) and mushrooms (oyster, straw, and split-gill mushroom) were subjected to the proximate and mineral composition analysis according to the AOAC method [26]. The protein was analyzed using the Kjeldahl method (AOAC 992.23) and the total fat content was determined after acid hydrolysis and solvent extraction using the Soxhlet™ apparatus (992.06). The dietary fiber was analyzed by using the enzymatic gravimetric method as mentioned by AOAC 985.29 and the ash content was determined by heating a sample in a muffle at 550 °C as mentioned by AOAC 945.46. The moisture content was measured by drying a sample in a hot-air oven at 105 °C (AOAC 927.05). The analysis was done in triplicate.

2.3. HPIS preparation

2.3.1. Preparation of HPIS for the just-about-right (JAR) analysis

The legume and mushroom containing higher amount of protein and mineral based on the proximate and mineral composition analysis were chosen as parts of the ingredients in the formulation of HPIS. The formula and the preparation of the HPIS followed the modified method of Farzana et al. [14] and preliminary research. The black bean and Hom Mali rice were ground using a multipurpose dry mill (NT-500D, Nanotech, China) and sieved through a 100-mesh sieve. The fresh oyster and split-gill mushroom were chopped into small pieces (0.5 × 0.5 cm). Finely ground Hom Mali rice (2.5 %) and black beans (12 %) were mixed with mung bean protein powder (12 %), oyster (12 %), and split-gill mushroom (12 %). The mixture was added with water (49.5 %) and blended using a blender (BE-127A, Otto, Thailand) at the highest speed for 20 min until the mixture blended homogeneously. The homogeneous slurry was then heated at 98±2 °C for 45 min until all the ingredients were thoroughly cooked. The HPIS mixture was rested until the temperature reached 25 °C after that the HPIS mixture was dried using a drum dryer (TDD300, P.S.A.21 Limited Partnership, Thailand). The HPIS mixture (300 g) was poured into the drum dryer gradually while the roller rotated continuously. The drying condition was set with a constant roller surface temperature of 150 °C. The roller speed was set at 3 rotations per minute (RPM). All the drying batches were continually processed until the mixture was depleted. The HPIS was sieved through an 80-mesh sieve and packed in a ziplock foil until further use. The HPIS was subjected to JAR analysis before the study on the effect of drum dryer rotation speed on the HPIS.

2.3.2. HPIS using drum dryer with different rotation speeds

The HPIS from 2.3.1 was used to study the effect of different rotation speeds. The HPIS was prepared using a double drum dryer with constant roller surface temperature at 150 °C with different roller rotation speeds (3, 5, 7, and 9 RPM). The HPIS dried with a drum dryer speed set at 3 RPM was designated as the control in this study. The physicochemical properties and sensory attributes of the HPIS were analyzed and evaluated.

2.3.3. Mineral supplementation on HPIS

The minerals (calcium, iron, and zinc) were incorporated into the chosen HPIS formulation from 2.3.2, with the HPIS preparation following the method described in 2.3.1, to provide sufficient mineral intake for the elderly. The amount of minerals added followed the Thai recommended daily intake (RDI); 800 mg of calcium, 10 mg of iron, and 15 mg of zinc per day [27].

2.4. Scanning electron microscope (SEM)

The particle characteristics of the HPIS powder produced under different drying conditions were evaluated using a scanning electron microscope (JSM-5419-LV, JEOL, Japan) and acquired in the range of 200–800 magnifications. The sample for acquiring the micrographs was prepared and mounted on double-sided tape on the used aluminum stubs. Further, the adhered samples were coated with gold–palladium (60:40) at an accelerated voltage of 15 kV following the method described in the research by Yadav et al. [28].

2.5. Physicochemical properties

The HPIS from the preparation from 2.3.2 was subjected to physicochemical properties analysis. The proximate and mineral composition was done according to the AOAC method [26]. The color and the viscosity of the HPIS were measured following the method described by Samakradhamrongthai et al. [29]. The color values: L* (lightness), a* (greenness-redness), and b* (blueness-yellowness) of the HPIS were measured at room temperature using a colorimeter (Color Quest XE, Color Global, USA). The viscosity of the HPIS was measured using a viscometer (Model DV-E, Brookfield Engineering Laboratories, Inc., USA). The HPIS powder was mixed with water at 1 % w/v and the viscosity was measured at a rotational speed using an S-64 spindle at 10 RPM. The physicochemical properties measurement was done in triplicate.

2.6. Sensory evaluation on HPIS

The sensory evaluations throughout this study were performed under the same protocol, which was approved by the Office of Human Research Ethics Committee, Chiang Mai University (Approval No: CMUREC No. 65/096). The principles outlined in the Helsinki Declaration were followed in the conduct of this investigation. The sensory evaluation (n = 50) and consumer acceptance (n = 200) were done by untrained panelists aged 60 years and over recruited from around Chiang Mai, Thailand. Before the study, the participants were asked about their familiarity with instant soup and their ability to swallow instant soup-type products. The participants were also required to provide their written consent and sign the consent form. The HPIS powder (20 g) was presented in a white paper plate, whereas the soup was prepared by reconstituting the powder (10 g) with hot water (1:10 w/w) at 98 °C and poured into a plastic container with a lid, with both types of the samples were coded with a three-digit number and evaluated in a monadic order, following a balanced-incomplete design [30]. The soup sample was served warm (approx. 50 °C) to each panelist in random sequence. During each soup sample, the panelists were instructed to halt and rinse their palates with prepared drinking water at room temperature.

The adequacy of the five attributes ("color", "bean flavor", "mushroom flavor", "salty taste", and "texture (roughness)") of the HPIS from 2.3.1 before the study on the effect of the drying condition, was evaluated by using "just-about-right" (JAR) bipolar scales of five points ranged (from 5 = "much more" to 1 = "much less" with middle value 3 = "just about right"). Afterward, the sensory evaluation and consumer acceptance were carried out by using a 9-point hedonic scale (9 was "liked extremely" and 1 was "disliked extremely") [31] on the attributes of the powder (color and characteristic) and the soup (color, bean flavor, mushroom flavor, salty taste, texture (roughness), sensation after swallowing, and overall preference). The penalty analysis (PA) was carried out by transforming the initial scale of five points into one of three points. For that, the responses "much less" and "less" were grouped into a unique group named "much less" and the responses "more" and "much more" were grouped in a unique group named "much more" [32,33].

2.7. Statistical analysis

The obtained results were analyzed and reported as mean ± standard deviation. The statistical analysis was conducted using SPSS software version 25 (SPSS Inc., Chicago, IL, USA), where Duncan's Multiple Range Test (DMRT) was applied to determine the significance level at a 95 % confidence limit. The JAR results were examined by the PA to determine possible areas for product improvement based on consumer acceptability by emphasizing the most unfavorable characteristics in terms of likeness [34].

3. Results and discussion

3.1. Proximate and mineral composition of selected legumes and mushrooms

The results on the proximate and mineral composition of selected legumes (red kidney and black bean) and mushrooms (oyster, straw, and split-gill) are shown in Table 1. Black bean exhibited significantly ($p < 0.05$) higher protein (19.13 ± 0.48 g/100 g) and calcium content (2308.65 ± 113.07 mg/kg) than red kidney bean (16.71 ± 1.13 g/100 g and 1529.19 ± 100.45 mg/kg, respectively). Similar results were also obtained by Ref. [35]. Black beans are oval-shaped beans with a sweet flavor and a little white patch on the black exterior. Black beans are an excellent source of proteins that include many necessary amino acids, particularly lysine [11]. Black beans are a great source of phytochemicals such as saponins, anthocyanins, flavonols, and phenolic acids in addition to protein. These phytochemicals give black beans their powerful biological effects, which include antioxidant, anti-diabetic, anti-inflammatory, antimutagenic, anti-obesity, anti-cancer, and lowering the risk of coronary heart disease [11,36].

In terms of mushrooms, split-gill mushroom possessed the highest protein content (4.65 ± 0.61 g/100 g), compared to other mushroom types. Not only protein, but other responses also showed that split-gill mushroom contained significantly ($p < 0.05$) higher values on all responses, except for moisture content. Since the split-gill mushroom, *Schizophyllum commune*, is the most potent and most researched of all medicinal mushrooms, it has a long history of use as medicine in Far Eastern nations [37]. The investigation also showed that fat was undetected in oyster mushroom. Oyster mushrooms contain low fat content [38]. Oyster mushrooms are prized for their distinct flavor, taste, and texture as well as for their medicinal properties. Due to their low fat and cholesterol content, mushrooms are a perfect food for people with heart disease, diabetes, obesity, and anyone looking to lose weight. These mushrooms are beneficial for those who struggle with constipation and hyperacidity due to their high fiber content, and provide numerous health advantages,

Table 1
Proximate and mineral composition of selected legumes and mushrooms.

Responses	Legumes		Mushrooms		
	Red kidney bean	Black bean	Oyster	Straw	Split-gill
Total Energy^{NS} (Kcal/100g)	335.17 ± 5.17	335.04 ± 5.17	32.30 ± 0.44^{b}	31.03 ± 0.29^{b}	55.07 ± 1.05^{a}
Carbohydrate^{NS} (g/100g)	65.48 ± 1.22	62.85 ± 2.31	5.31 ± 0.03^{b}	4.22 ± 0.03^{c}	8.88 ± 0.36^{a}
Protein (g/100g)	16.71 ± 1.13^{B}	19.13 ± 0.48^{A}	2.77 ± 0.09^{b}	3.40 ± 0.31^{b}	4.65 ± 0.61^{a}
Fat^{NS} (g/100g)	0.78 ± 0.12	0.67 ± 0.08	ND	0.06 ± 0.01^{a}	0.06 ± 0.01^{a}
Crude Fiber (g/100g)	6.74 ± 0.30^{A}	4.70 ± 0.42^{B}	0.71 ± 0.01^{b}	0.62 ± 0.04^{c}	0.84 ± 0.05^{a}
Ash^{NS} (g/100g)	3.71 ± 0.23	3.90 ± 0.12	0.75 ± 0.08^{b}	1.07 ± 0.08^{a}	1.11 ± 0.19^{a}
Moisture^{NS} (g/100g)	13.32 ± 0.82	13.17 ± 0.75	91.17 ± 0.16^{a}	91.31 ± 0.61^{a}	85.28 ± 0.93^{b}
Calcium (mg/kg)	1529.19 ± 100.45^{B}	2308.65 ± 113.07^{A}	640.19 ± 0.8^{b}	599.11 ± 1.35^{c}	743.89 ± 0.66^{a}
Iron^{NS} (mg/kg)	38.14 ± 1.52	40.84 ± 2.42	7.31 ± 0.05^{b}	5.67 ± 0.38^{b}	40.10 ± 2.15^{a}
Zinc^{NS} (mg/kg)	15.99 ± 1.65	18.06 ± 1.07	3.87 ± 0.03^{c}	7.34 ± 0.19^{b}	26.23 ± 0.78^{a}

Data is shown as mean ± standard deviation (n = 3); Different uppercase superscript letter means significant different (p < 0.05) between type of cereal; NS superscript letter means no significant difference (p > 0.05) between type of cereal. Different lowercase superscript letter means significant different (p < 0.05) between type of mushroom.

such as immunomodulating actions, antibacterial, antidiabetic, and antioxidant qualities [37,39–42].

3.2. JAR analysis on HPIS formulation

Table S1 shows the demographic information on the 50 elderly panelists. In this study, 80 % of the respondents were female elderly. Most of the respondents were in their early 60s (74 %), had congenital disease (60 %), no food allergies (86 %), and without swallowing problems (86 %). Based on the data on the RTE behavior of the consumer (Table S2), all the respondents (100 %) had ever eaten RTE food, with the majority choosing to eat ready-made porridge (60 %) and instant noodles (52 %) due to its low time of preparation and convenience (64 %). Most of the elderly liked to eat foods with slightly (26 %) and moderately soft texture (46 %). Many health problems associated with aging, such as frailty and physical, sensory, and cognitive deficits, lead to appetite loss and, as a result, negatively impact the life quality of the person [43]. Another element affecting the health of elderly persons is age-related problems with swallowing food [44,45]. The three processes of swallowing—oral, pharyngeal, and esophageal—can all be impacted by aging, concurrent medical conditions, and medication use. The effectiveness of the oral phase can be diminished in elderly people due to decreased jaw strength, dental alterations, and decreased salivary output. Additionally, it has been demonstrated that aging increases the duration of the pharyngeal and esophageal stages [46]. The elderly with chewing and swallowing issues prefer soft foods since they require fewer chews and take less time in the mouth than harder items [47].

The Just-About-Right percentage of panelists giving consumer ratings on attributes of the HPIS formula based on a collapsed JAR scale regarding the color, bean flavor, mushroom flavor, salty taste, and texture (roughness) (Fig. 1). As shown in the figure, the JAR results on all attributes except texture (roughness) exceeded 70 %. Based on the evaluation of the adequacy of 5 attributes of the HPIS, the texture was found to be on the rougher side. Individual food sensory perception abilities are either directly or indirectly related to physiological processes such as oral manipulation (chewing and swallowing), chemical sensory (gustation and olfaction), and sensory perception of touch. People who had trouble swallowing and chewing food had decreased appetites and focused more on the texture of their food [47]. The HPIS formula was adjusted accordingly before the properties investigation of the HPIS produced using different drum drying conditions. The HPIS formula was also subjected to the protein and minerals analysis before the JAR analysis, revealing that the HPIS exhibited protein (38.09 $\pm$ 1.03 g/100 g), calcium (94.71 $\pm$ 0.26 mg/100 g), iron (9.69 $\pm$ 0.26 mg/100 g), and zinc (3.94 $\pm$ 0.06 mg/100 g).

3.3. Morphological analysis on HPIS using scanning electron microscopy (SEM)

The SEM image of the HPIS under different drying conditions is depicted in Fig. 2a–d. Similar findings were discovered by Taşkın & Savlak [48], who claimed that drum drying changed the structural integrity of powders due to the physicochemical and thermal effects of process conditions such as gelatinization and degradation. Soup powder SEM micrographs showed broken starch granules and odd forms with unevenly distributed networks. In addition, there were also noticeable tiny, agglomerated granules, primarily protein or starch particles. Where cavities, fissures, and fractures were found, a structure resembling a porous layer was visible.

3.4. Physicochemical properties of HPIS

The analysis of the physicochemical properties of HPIS using different drying rotation speeds revealed the treatment affected the properties significantly ($p < 0.05$), except for the moisture content and the L* value of the instant soup (Table 2). It was shown that

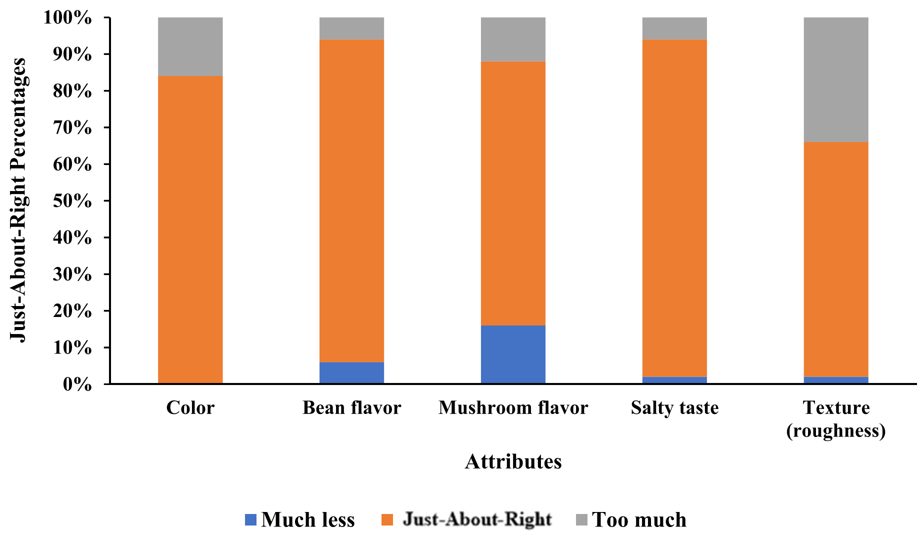

Fig. 1. Just-About-Right percentage of HPIS provided for elderly consumers using the Just-About-Right scale.

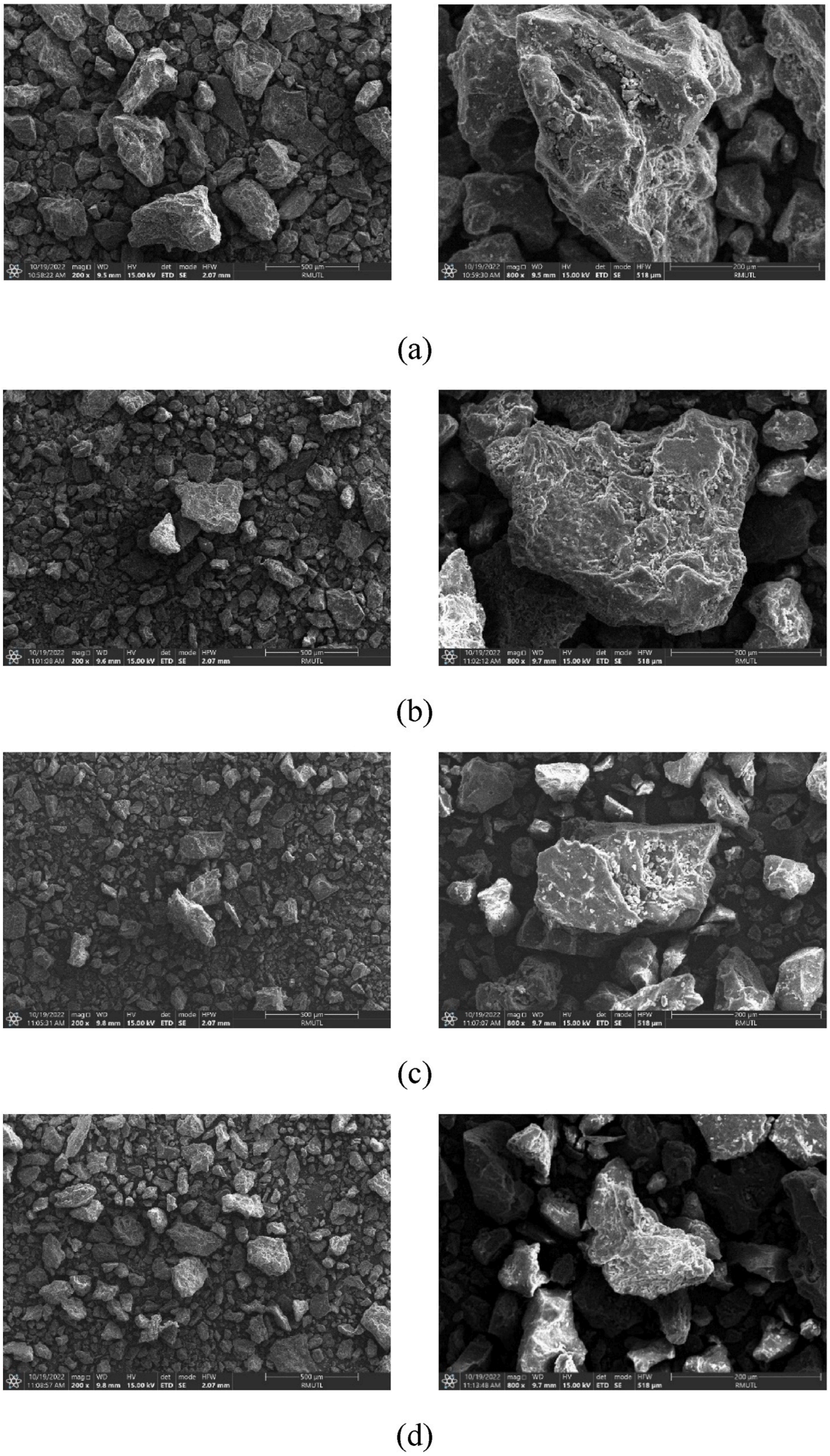

Fig. 2. SEM image of HPIS under different rotation speeds per minute (RPM) and magnification; (a) HPIS from drum dryer at 3 RPM; (b) HPIS from drum dryer at 5 RPM; (c) HPIS from drum dryer at 7 RPM; (d) HPIS from drum dryer at 9 RPM.

Table 2
Physicochemical properties of HPIS produced under different rotation speeds per minute.

Responses	Rotation speed per minute (RPM) of drum dryer			
	3	5	7	9
Powder Color L*	57.40 ± 0.11[b]	58.52 ± 0.62[b]	57.43 ± 0.38[c]	59.84 ± 0.17[a]
Powder Color a*	1.93 ± 0.08[b]	2.33 ± 0.06[a]	1.21 ± 0.03[c]	1.10 ± 0.01[d]
Powder Color b*	7.68 ± 0.25[b]	8.49 ± 0.14[a]	5.52 ± 0.08[c]	5.30 ± 0.02[c]
Instant soup Color L*[NS]	31.77 ± 1.57	32.18 ± 1.27	32.69 ± 1.12	33.09 ± 1.15
Instant soup Color a*	1.19 ± 0.90[a]	1.49 ± 0.67[a]	−0.38 ± 0.05[b]	−0.53 ± 0.06[b]
Instant soup Color b*	8.35 ± 0.87[b]	10.81 ± 1.10[a]	7.02 ± 0.42[c]	6.68 ± 0.44[c]
Moisture (%)[NS]	3.87 ± 0.05	3.95 ± 0.03	3.97 ± 0.02	3.98 ± 0.04
Viscosity (cP)	2319.00 ± 98.47[c]	1898.33 ± 57.66[d]	3440.33 ± 114.61[b]	4258.67 ± 197.48[a]
Protein (g/100g)	38.13 ± 0.83[b]	39.52 ± 0.07[a]	39.59 ± 0.07[a]	39.67 ± 0.59[a]
Calcium (mg/100g)	94.66 ± 0.39[a]	91.94 ± 0.05[b]	89.33 ± 0.42[c]	88.70 ± 0.01[d]
Iron (mg/100g)	9.84 ± 0.05[d]	10.60 ± 0.0610[a]	10.19 ± 0.06[c]	10.42 ± 0.11[b]
Zinc (mg/100g)	3.86 ± 0.11[d]	4.65 ± 0.07[a]	4.46 ± 0.06[c]	4.83 ± 0.03[b]

Remarks: Data is shown as mean ± standard deviation (n = 3); Different superscript letter means significant different ($p < 0.05$) between formula; NS superscript letter means no significant difference ($p > 0.05$) between formula.

increasing the rotation speed affected the L* value of the powder positively, while the a* and b* values were affected negatively. Similarly, the instant soup color (a* and b* values) also showed a similar trend. The highest L* value of the powder was exhibited by the powder using the highest speed of the drum dryer (9 RPM), which was 59.84 ± 0.17, and it also exhibited the lowest a* and b* values (1.10 ± 0.01 and 5.30 ± 0.02, respectively). Pua et al. [49] also discovered that the L* value was positively affected linearly by the drum's rotation speed. The decreasing drum surface temperature brought about by the faster speed of the drum led to the rising L* value. This can be the result of a higher product throughput rate, which requires the drums to absorb more heat to remove a higher moisture load. As the drum speed was raised, the film thickness and drying time decreased, which also contributed to the drop in drum surface temperature. Lower drying temperature leads to lower occurrence of nonenzymatic browning reactions and pigment degradation [29].

The primary factor affecting food viscosity is starch. Starch granules are harmed by drum drying, which results in viscosity loss. At temperatures greater than the native starch gelatinization temperature, pregelatinized starches are less dense. Yet at lower temperatures, they can raise viscosity [48]. It was observed that the viscosity of the HPIS significantly ($p < 0.05$) affected by the speed of the drum dryer, with the viscosity values were in the range of 1898.33–4258.67 cP. The results on the viscosity measurement also showed a similar trend, with the increasing drum speed, which lowered the temperature, increasing the viscosity. Drum rolls become more heated under pressure as the rotational speed drops, and the surface temperature rises. Due to the damaging heat effects produced at high pressures and low rotational speeds, starch granules were more severely disrupted and gelatinized, and their viscosity was reduced.

In terms of the protein and minerals of the HPIS, these responses were significantly ($p < 0.05$) affected by different drum dryer speeds. The HPIS exhibited protein, calcium, iron, and zinc in the range of 39.67–38.13 g/100 g, 88.70–94.66 mg/100 g, 9.84–10.42, and 3.86–4.83 mg/100 g, respectively. It was observed that a drum dryer with higher speed, which lowers the temperature of the system, provided HPIS with higher amounts of protein and minerals, except c calcium. Taşkın & Savlak [48] stated that denaturation of

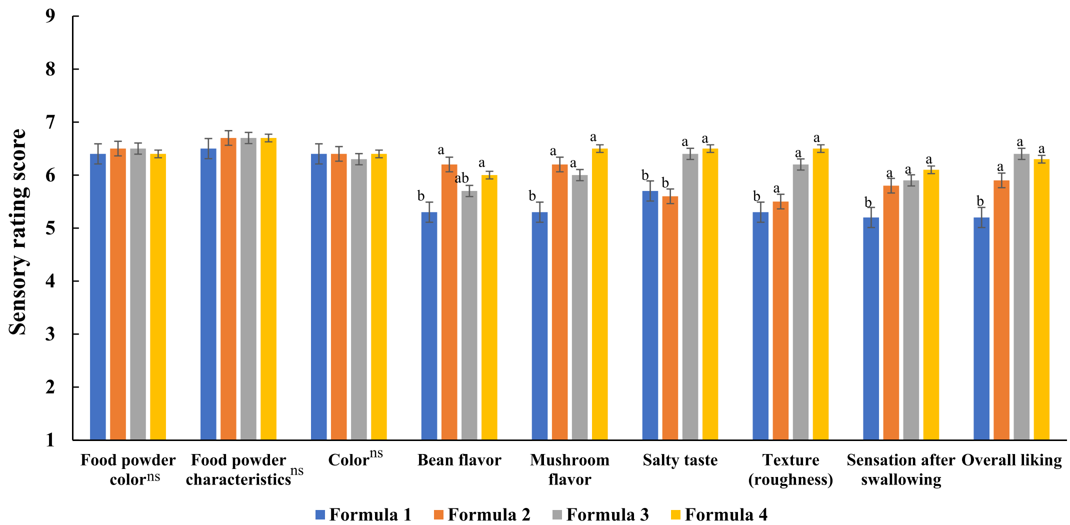

Fig. 3. Sensory evaluation of the HPIS from drum dryer at 3 RPM (Formula 1); 5 RPM (Formula 2); 7 RPM (Formula 3); and 9 RPM (Formula 4).

the protein also occurred at higher temperatures of the drum drying process, which was shown in Table 2, that lower rotating speed led to a higher temperature of the system, finally resulting in a product with lower protein content. Not only protein but minerals were also affected similarly. Heat treatment was found to affect the bioavailability of iron and zinc [50]. In comparison with other research on the development of soup powder, the HPIS with selected legumes and mushrooms provides higher protein content than soup powder made from soy-mushroom-moringa leaf powder (6.92–16.05 %), chickpea (16.62–16.89 %), and tempeh (9.76–30.01 %) [14,25,51].

3.5. Sensory evaluation on HPIS

The sensory evaluation revealed all properties, except the powder (color and characteristics) and color of the soup, significantly ($p < 0.05$) affected by the rotating speed of the drum dryer (Fig. 3). Chemosensory impairment in elderly people can be resolved with the use of certain methods. One strategy was incorporating natural ingredients with a strong flavor or umami taste [47]. Results of the sensory evaluation revealed that the faster the speed of the drum dryer, the score for the bean flavor (5.3–6.2), mushroom flavor (5.3–6.5), and salty taste (5.6–6.5) were higher. Lower rotating speeds led to the higher temperature of the drum dryer [49]. Higher temperature during drying led to the decomposition of thermosensitive phytochemicals, including flavor compounds [52], and finally affected the sensory properties of the HPIS. Furthermore, there is a stronger response to salts at lower temperatures [53], which explained the higher score on the salty taste of the HPIS produced from the drying method employing high rotating speed. Chen et al. [54] and Han et al. [55] also found that the formation and intensification of flavor compounds of legumes and mushrooms are affected by temperature, as suggested in Xie et al. [56] investigation.

For safe swallowing, food texture features such as hardness, cohesiveness, stickiness, etc., are essential. Additionally, geometric characteristics, such as food size and form, are linked to the risk of choking [47]. The structural changes that occur during drying because of applying heat produce a firmer texture [57]. As can be seen from the figure, the higher speed of the drum dryer led to a higher score of the texture-related attributes (texture "roughness" and sensation after swallowing) evaluated by the panelists. Drum rolls become more heated under pressure as the rotational speed drops, and the surface temperature rises. As a result, the starch granules were more severely disrupted and gelatinous due to the destructive heat effects produced at low rotating speeds [48]. The higher prevalence of disrupted starch granules and the destructive effect of the high temperature during their processing contributed to the rougher texture and sensation after swallowing the product.

3.6. Nutritional assessment on HPIS formula

Based on the results of the physicochemical and sensory evaluation, the HPIS using the drum dryer with the speed of 7 RPM was evaluated further in this study. The proximate analyses revealed that 100 g of the HPIS contained 6.61 ± 0.02 % moisture, energy of 343 ± 0.10 Kcal, 38.80 ± 1.10 g carbohydrate (including dietary fiber), 42.50 ± 0.07 g protein, and 1.99 ± 0.01 g total fat (Table 3). The minerals (calcium, zinc, and iron) supplementation was done to meet the required amount stated by the Thai RDI (800 mg of calcium, 10 mg of iron, and 15 mg or zinc) [Thailand Ministry]. After the supplementation, the HPIS exhibited 1053 ± 10.02 mg calcium, 10.21 ± 0.09 mg iron, and 18.75 ± 1.01 zinc. The sensory quality assessment was done by 200 elderlies, 68 males (34 %) and 132 females (66 %), with most of the consumers being elderly at age 60–65 (67.5 %). The sensory rating score of the HPIS showed the product was moderately liked (7.1–7.5) by the consumer. The majority of the consumers accepted the product (97 %) and were interested in purchasing the product (91 %) if it was available on the market. Other researchers also obtained similar results [58], and higher results were obtained compared to the pumpkin cream soup with tempeh supplementation [25].

Table 3
Proximate, mineral, and physicochemical quality of HPIS final formula.

Responses	Observation value of product
Powder Color L*	50.5 ± 1.23
Powder Color a*	1.49 ± 0.10
Powder Color b*	8.00 ± 0.54
Instant soup Color L*	32.49 ± 1.02
Instant soup Color a*	−0.40 ± 0.06
Instant soup Color b*	6.98 ± 0.04
a_w	0.29 ± 0.02
Moisture (%)	6.61 ± 0.02
Viscosity (cP)	3420.25 ± 115.34
Calories (Kcal)	343 ± 0.10
Carbohydrates (Include dietary fiber) (g/100g)	38.80 ± 1.10
Protein (g/100g)	42.50 ± 0.07
Dietary fiber (g/100g)	20.00 ± 0.05
Total Fat (g/100g)	1.99 ± 0.01
Ash (g/100g)	9.14 ± 0.02
Calcium (mg/100g)	1053 ± 10.02
Iron (mg/100g)	10.21 ± 0.09
Zinc (mg/100g)	18.75 ± 1.01
Sugar (g/100g)	1.09 ± 0.01
Sodium (mg/100g)	868 ± 1.25

4. Conclusion

This study successfully incorporated selected legume and mushrooms; black bean, oyster mushroom, and split-gill mushroom, due to their considerable amounts of protein (19.13 ± 1.13, 2.77 ± 0.09, and 4.65 ± 0.61 g/100 g, respectively), calcium (2308.65 ± 113.07, 640.19 ± 0.80, and 743.89 ± 0.66 mg/100 g, respectively), iron (40.84 ± 2.42, 7.31 ± 0.05, and 40.10 ± 2.15, mg/100 g respectively), and zinc (18.06 ± 1.07, 3.87 ± 0.03, and 26.23 ± 0.78, mg/100 g respectively), in the formulation of HPIS. The use of drum drying significantly affected the physicochemical and sensory qualities of the HPIS, with the use of 7 RPM resulting in an adequate product and moderately like (7.1–7.5) by the elderly. The majority of the consumers also accepted the product (97 %) and were interested in purchasing the product (91 %) if it was available on the market. The utilization of these specific legumes and mushrooms resulted in an instant soup product with adequate nutrition for the consumption of the elderly and following the Thai RDI.

The findings in this study could be used for the development of instant soup powder from different ingredients, especially specific legumes (black bean) and mushrooms (oyster mushroom and split-gill mushroom). Future investigation of other drying parameters could be done to provide a deeper understanding of its effect on the qualities of instant soup powder. Further research after HPIS consumption might also deliver a greater understanding of its influence on the well-being of the consumer. Nevertheless, different legumes and mushrooms used in the formulation of instant soup products, along with different drying methods, might produce products with different properties. Moreover, as this study focused on the elderly population, investigation of an instant soup product at different populations might provide different outcomes.

Data availability statement

The data generated during the current study are available from the corresponding author upon reasonable request.

Ethical approval

This study was conducted following the guidelines presented in the Declaration of Helsinki. The Office of Human Research Ethics Committee, Chiang Mai University (Approval No: CMUREC No. 65/096).

CRediT authorship contribution statement

Rajnibhas Sukeaw Samakradhamrongthai: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Taruedee Jannu:** Validation, Investigation, Formal analysis, Data curation. **Tussanun Tongboonchu:** Validation, Investigation, Formal analysis, Data curation. **Wanalee Sangpimpa:** Validation, Investigation, Formal analysis, Data curation. **Phatthamon Srichan:** Validation, Investigation, Formal analysis, Data curation. **Orapan Seangsee:** Validation, Investigation, Formal analysis, Data curation. **Gerry Renaldi:** Writing – original draft, Validation, Methodology, Formal analysis, Data curation. **Preeyabhorn Detarun:** Writing – review & editing, Visualization, Validation, Supervision, Project administration, Investigation, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:Rajnibhas Sukeaw Samakradhamrongthai reports financial support was provided by Prince of Songkla University. Preeyabhorn Detarun reports a relationship with Prince of Songkla University that includes: funding grants. Co-author, Rajnibhas Sukeaw Samakradhamrongthai, was previous worked at Prince of Songkla University.

Acknowledgments

This research was supported by the National Science, Research and Innovation Fund (NSRF) and Prince of Songkla University, Thailand (Grant NO. AGR6505031M and AGR6505031d). The authors would also like to thank the Faculty of Agro-Industry, Chiang Mai University, Thailand, for supporting laboratory facilities and instruments for this research.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e35810.

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