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Gelling, textural, and sensory properties of grass jelly formulated with different starches

Shiyun Zhou[1], Maninder Meenu[1] and Baojun Xu[1*]

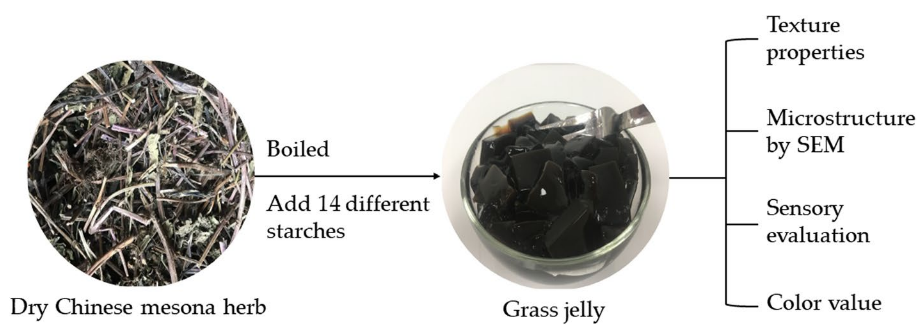
Abstract

Starch from different sources exhibits different properties when used as an ingredient for developing a food. There are many recipes reported to produce grass jellies from different starches. However, the impact of starch from a particular source on the quality of grass jelly has not been explored untill now. Thus, in present study, blume polysaccharide extract from mesona herb was mixed with starch slurries from 14 different sources while boiling to prepare grass jellies. These grass jellies were further investigated for their microstructure, color, cohesiveness, gumminess, hardness, springiness, and chewiness to explore the impact of starch source of grass jellies quality. Among all the starches, the pea starch-based grass jelly presented the highest texture qualities in terms of hardness, gumminess, and chewiness. Whereas corn starch-based grass jelly exhibited higher values for cohesiveness and springiness. Overall, grass jelly formulated with pea and corn starch performed well in terms of texture properties analysis among other samples. The canna grass jelly was the most preferred by panelists in terms of sensory properties. All samples showed to have a network structure under scanning electron microscopy (SEM). The color of all jelly samples was dark and an insignificant difference was observed in color values of all the samples. Based on all parameters discussed in this study, pea starch, corn starch and canna starch are highly preferred for producing grass jelly from Chinese dry mesona herb. As the grass jellies formulated with pea starch, corn starch, and canna starch exhibit improved quality parameters, more studies need to be conducted to further explore the optimal proportion of these starches and herbal extracts as well as their impact on gelation for developing novel grass jellies. In addition, the viscoelastic properties of formulated grass jelly samples also need to be explored to understand addition properties. It is also important to explore the reason behind the high values for the textual properties of pea starch grass jelly compared to 13 other grass jelly samples formulated with different starch sources.

Keywords Grass jelly, Starch, Texture profile analysis, Sensory evaluation, Scanning electron microscopy

*Correspondence:
Baojun Xu
baojunxu@uic.edu.cn
Full list of author information is available at the end of the article

Graphical Abstract



Introduction

Grass jelly is a kind of popular jelly-like traditional food that originated in South China (Administration, 2018). The consumption of grass jelly is suitable for people of all age groups. Its consumption is especially recommended for patients with dry throat and throat aches (Zhao, 2020). In ancient China, grass jelly was cherished both as medicinal as well as edible food (Wu, 2017; Zhao, 2020). Recently, the Chinese population has been consuming grass jelly as a dessert covered with condensed milk and mixed with fruits in summer to relieve heat in the body. The black grass jelly is frequently prepared from the Chinese mesona herb (Administration, 2018; Wu, 2017; Zhao, 2020).

Chinese mesona herb is widely spread throughout China including Zhejiang, Jiangxi, Guangdong, and Guangxi provinces (Administration, 2018). The herb usually grows under fruit trees as secondary crops in grassy, dry, and sandy areas (Edita, 1977). Mesona herb contains mesona blume polysaccharide, a kind of gel-like saccharide which can be converted to jelly followed by boiling and the addition of starch (Lin & Zhu, 1992). This mesona blume polysaccharide is reported to contain significant anti-lipid peroxidation activity (Yang et al., 2002).

Starch is the most frequently available nutrient in various kinds of food and is insoluble in cold water. Starch is a polymeric carbohydrate containing a large number of glucose units connected together, basically known as linear amylose and branched amylopectin. Starches are typically composed of 20 to 25% amylose and 75 to 80% amylopectin by weight (Donmez et al., 2021).

Mixing starches in warm water generates a paste to be used as a thickening and stiffening agent. When starch is heated in water, the starch granules are swelled and lead to the melting of the double-helical structure. The breaking of intermolecular bonds allows enhanced interaction with water which leads to solubilization of starch in water (Jenkins & Donald, 1998; Xiong et al., 2013). After cooling, the starch exhibits gelation and maintained its gel structure (Shevkani et al., 2016). This is an irreversible process known as starch gelatinization. The starch with more amylose content exhibits lower cohesive properties and a higher crisp capability and vice versa (Zhou et al., 2018). While preparing grass jelly, starch reacts with the grass polysaccharides to form a stable network structure (Feng et al., 2008). Starch can be extracted from various plant sources such as potato, pea, mung bean, tapioca, and arrowroot. Potato starch is a frequently used ingredient in noodles, potato chips, sauces, and cakes to maintain moisture and soft texture (Blech, 2004). Potato starch contains approximately 12.38% amylose content (Cheng, 2012). Potato starch also contains nearly 800 ppm phosphate which increases its swelling power and viscosity (Toshiko, 1983). Pea starch is one of the cheapest starches among the potato and corn starch samples (Li et al., 2003). It contains more amylose content compared to others, and the granules are also smaller compared to potato and corn starch samples (Sun et al., 2014; Zhang et al., 2016). Mung bean starch is also famous for making mung bean starch jelly (Xie et al., 2019). This jelly is appreciated for its unique taste and appearance in northern China. Mung bean has high nutritional and therapeutic values, and is responsible for lowering blood lipid levels, detoxification, sterilization, tumor inhibition, and cancer prevention (Hayat et al., 2014; Messina, 2014; Monk et al., 2015). Corn starch is also among the most common starches used in cooking. It is reported to contain around 26.0% amylose content (Cheng, 2012). Sweet potato starch, tapioca starch, potato starch, and arrowroot starch are extracted from root crops which are considered to exhibit more free swelling and non-congealing properties (Collado et al., 2001).

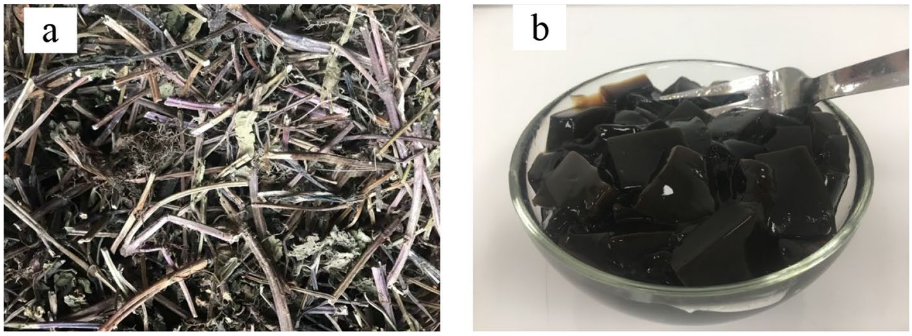


Fig. 1 **a** Chinese mesona herb; **b** a typical Grass jelly sample

Different kinds of grass jellies and recipes have evolved these days due to the recent increase in the popularity of grass jelly among consumers of different age groups. These grass jellies are prepared with different kinds of starches. However, studies on the impact of different kinds of starch on the final microstructure, texture properties, sensory evaluation, and color variation of these grass jellies are scarce. Previously, studies were conducted to explore the effect and usage of mesona blume polysaccharide on human health, however, fewer studies have discussed the properties of the grass jelly. Thus, this study aims to develop Chinese mesona herb-based grass jelly using 14 different starchs and to explore the best starch to develop mesona herb grass jelly with the best microstructure, color, textural and sensory properties.

Materials and methods

Materials

The Chinese dry mesona herb (*Platostoma palustre*), as shown in Fig. 1(a), was bought from Longyan, Fujian, China. The dietary alkali (Na_2CO_3), potato starch, pea starch, mung bean starch, corn starch, wheat starch, rice starch, lotus root starch, sweet potato starch, canna starch, tapioca starch, and water chestnut starch were bought from the local market in Zhuhai, Guangdong, China. The chestnut starch, kudzu root starch, and Chinese yam starch were isolated in our laboratory, the properties of these starchs have been published in our previous papers (Guo et al., 2019; Wang et al., 2018b).

Starch isolation

The chestnut starch, kudzu root and Chinese yam (100 g) were kept in 0.3% sodium sulfite solution (500 mL) at room temperature. After 24 h, these samples were blended and resultant slurry was sieved using 100 and 200 mesh sieves. Then, filtrates were mixed with distilled water (1:5 v/v) and kept for 12 h to collect precipitates. These precipitates were washed with distilled water and centrifugation for 15 min at 3500 rpm followed by drying at 40 °C for 24 h. The dried starch samples were pulverized and sieved through a 100-mesh sieve. The resultant starch samples were stored in sealed polyethylene bags till use.

Preparation of grass jelly

The mesona herb was first bought from Sanming, Fujian and transported to Zhuhai, Guangdong as a dry herb. The herb was stored in a dry place at 4℃ before experiments. During the experiments, the mesona herb (150 g) was first washed thrice with distilled water. After washing, water was drained off and herbs were cut off into small pieces followed by thorough mixing with 4.5 g dietary alkali which can extract blume polysaccharide from the herb. Then, the mesona herb was boiled with 3,000 mL water using an induction cooktop up to 800 W for 40–50 min with continuous stirring. After boiling, the dark-colored extracted fluid from the mesona herb was strained using a filter cloth. The remaining herbs in filter cloth were further pressed to remove fluid containing the mesona blume polysaccharide. The herb fluid was divided into 14 portions (150 mL for each). Furthermore, starch samples from different sources (4.5 g) were mixed with 50 mL water in different cups to form a starch slurry. These starch slurries were added steadily to 14 different mesona extracts fluid while boiling on an induction cooktop set at 800 W followed by continuous stirring with a glass rod. The mixture was immediately transferred to the container as soon as the gelling of mesona extracts was started. The samples formulated with a different starch present variation in their boiling time as mentioned in Table 1. The resultant 14 grass jelly samples were put in a 4 °C refrigerator for 1 h. After cooling, the final grass jellies were obtained and a typical grass jelly is shown in Fig. 1(b).

Texture profile analysis (TPA)

The texture analysis of grass jelly was conducted using a previously reported method (Khouryieh et al., 2004).

Table 1 Formulation time of grass jelly prepared using different starches

Sample name	Herb fluid (mL)	Water (mL)	Starch (g)	Formulation Time (min)
Potato starch grass jelly	150	50	4.5	1
Pea starch grass jelly	150	50	4.5	1
Mung bean starch grass jelly	150	50	4.5	1
Corn starch grass jelly	150	50	4.5	1
Wheat starch grass jelly	150	50	4.5	2
Chestnut starch grass jelly	150	50	4.5	2
Rice starch grass jelly	150	50	4.5	2
Lotus root starch grass jelly	150	50	4.5	2
Sweet potato starch grass jelly	150	50	4.5	2
Canna starch grass jelly	150	50	4.5	1
Tapioca starch grass jelly	150	50	4.5	2
Kudzu root starch grass jelly	150	50	4.5	2
Water chestnut starch grass jelly	150	50	4.5	2
Chinese yam starch grass jelly	150	50	4.5	1

The gel was poured into petri dishes (90 mm in diameter) for testing. The texture analyzer (Brookfield CT3 4500, AMETEK Commercial Enterprise Co. Ltd., Middleboro, MA, U.S.A.) was used to test the samples with 15 mm in height and 90 mm in diameter by using the TA5 probe. The test mode operated in the analyzer was TPA, the trigger force was 5.0 g, the test speed was 1 mm/s and the deformation was 4 mm. The texture properties of grass jelly included hardness, springiness, cohesiveness, gumminess, and chewiness. All the tests were conducted in triplicate.

Sensory evaluation

The sensory evaluation of grass jelly samples was performed by 10 panelists who were randomly selected in school (including teachers and students) and trained by descriptive tests before the formal testing according to the general practice of sensory evaluation. During the whole sensory evaluation, panelists are separated one by one into sensory cubicles to restrict communication between them. Besides, the whole sensory evaluation was executed at one specific area in the laboratory building in Zhuhai, Guangdong, on a cloudy day around 20–25 °C. During the sensory evaluation, all the samples were randomly labeled with 3-digit IDs. Samples were provided along with a cup of water. All panelists were told to drink water before tasting the samples. The sensory evaluation was conducted in three parts. Part 1 included an evaluation of the appearance, texture, flavor, and overall acceptability of each sample. Panelists gave scores to the samples from number 1–9 based on whether they liked the grass jelly extremely, like very much, like moderately, like slightly, neither like nor dislike, dislike slightly, dislike moderately, dislike very much, or dislike extremely, respectively. In Part 2, the rubbery level of grass jelly was assessed while tasting. Scores 1 to 6 reflected the jelly as not rubbery, a trace of rubbery, slightly rubbery, rubbery, very rubbery to extremely rubbery. Part 3 evaluated the ranking of samples from 1 to 14 for individual preference. All the evaluation forms are shown in the supplemental figures. All the tests were conducted under the agreement with all the panelists. All the results were collected after the sensory evaluation was done on the same day.

Scanning electron microscopy analysis

The grass jelly samples were poured into 50 mL centrifuge tubes and stored at -80℃. After 24 h, samples were freeze-dried for 24 h. The morphology of each sample was explored by scanning electron microscopy (EVO-18, Zeiss, Oberkochen, Germany) at 200 and 500-fold magnification with an accelerating voltage of 3 kV.

Determination of color values

The color values namely, L^* (lightness), a^* (redness and greenness), and b^* (yellowness and blueness) of grass jelly were measured using Hunter colorimeter (D-25, Hunter Lab Associates Inc, Reston, USA). Before the experiment, the machine was calibrated with a CR-A43 white plate. The L^* value ranging from 0 to 100 represented black to white color. In case of a^*, "+" indicated red, and "-" indicated green, for b^* value, "+" indicated yellow and "-" indicated blue. The color values of samples were analyzed in triplicate.

Statistical analysis

The TPA and color values of samples were tested in triplicates and sensory evaluation was conducted in duplicate. The results were expressed as mean ± standard deviation. The significant differences among the mean values ($p < 0.05$) of parameters were determined using one-way analysis of variance (ANOVA) by employing IBM SPSS Statistic 25.0 software.

Results

Morphological and physicochemical characterization of starches isolated from chestnut starch, kudzu root starch and Chinese yam starch

Three starch samples namely, chestnut starch, kudzu root starch and Chinese yam starch were isolated in our laboratory. The physicochemical and morphological characterization such as moisture content, swelling power, solubility, thermal properties, pasting properties, particle shape and size of these starch samples are published previously (Guo et al., 2019; Reddy et al., 2017; Wang et al., 2018b) and presented in Table 2. The moisture content of chestnut starch was 1.24 folds higher than kudzu root starch (10.91 ± 0.37%). Whereas the amylose content of chestnut starch was 1.54 folds higher than Chinese yam starch (22.23 ± 0.87%). The L* (101.95 ± 0.54) and a* (1.71 ± 0.02) values of chestnut sample were also higher compared to the other two starch samples. The thermal parameters To and Tp of kudzu root starch were 1.07 and 1.36 folds higher than To (62.84 ± 0.18 °C) and Tp (67.31 ± 0.26 °C) of chestnut starch samples. The Tc and ΔH of chestnut starch samples 1.33 and 23.95 folds lowered than the Tc of Chinese yam starch (95.27 ± 0.16 °C) and ΔH of kudzu root starch (15.57 ± 0.33 J/g), respectively. In case of pasting properties, PT, PV, BD and SB values of chestnut starch was 1.21, 1.04, 1.76 and 1.25 folds lower compared to PT (86.55 ± 0.12 °C) and PV (4585 ± 10 cP) of kudzu root starch, BD of Chinese yam starch

Table 2 Morphological and physicochemical characterization of starches isolated from chestnuts starch, kudzu root starch and Chinese yam starch (Guo et al., 2019; Wang et al., 2018b)

Parameters	Samples	Chestnut starch	Kudzu root starch	Chinese yam starch
Moisture (%)		13.5 ± 0.3[a]	10.91 ± 0.37[b]	11.35 ± 0.21[b]
Protein (%)			0.23 ± 0.04	
Fat (%)			0.16 ± 0.02	
Ash (%)			0.14 ± 0.08[a]	
Amylose (%)		34.17 ± 0.48[a]	23.34 ± 0.77[b]	22.23 ± 0.87[b]
Color parameters	L*	101.95 ± 0.54[a]	94.34 ± 0.3[b]	87.61 ± 0.28[c]
	a*	1.71 ± 0.02[a]	1.23 ± 0.16[b]	0.25 ± 0.01[bc]
	b*	-7.50 ± 0.17[a]	-0.94 ± 0.07[b]	1.13 ± 0.02[c]
Swelling power (g/g)		0.19 ± 0.001[a]	2.34–13.42	10.21 ± 0.49[b]
Water solubility index (g/100 g)		10.52 ± 0.06	–	–
Water retention capacity (g/g)		0.92 ± 0.02	–	–
Solubility (%)		–	0.59–3.72	19.44 ± 0.49
Thermal parameters	To (°C)	62.84 ± 0.18[a]	66.93 ± 0.85[b]	63.65 ± 0.24 [a]
	Tp (°C)	67.31 ± 0.26[a]	91.82 ± 0.78[a]	80.13 ± 0.21[b]
	Tc (°C)	71.68 ± 0.31[a]	83.71 ± 0.55[b]	95.27 ± 0.16[c]
	ΔH (J/g)	0.65 ± 0.00[a]	15.57 ± 0.325[b]	8.59 ± 0.24[bc]
Particle size (μm)		1.2—517.2	10.09 ± 0.29	8–25
Particle shape		Oval to spherical shape, elliptical	spherical, hemispherical and polygonal	Polygonal, elliptical
Pasting parameters	PT (°C)	71.82 ± 0.03[a]	86.55 ± 0.12[a]	78.30 ± 0.05[b]
	PV (cP)	4375.33 ± 50.81[a]	4585 ± 10[b]	4453 ± 96[a]
	TV (cP)	3057.33 ± 85.33[a]	2644 ± 9[b]	2127 ± 51[b]
	BD (cP)	1318.00 ± 40.63[a]	1944 ± 11[b]	2325 ± 45[c]
	FV (cP)	4447.00 ± 80.57[a]	4372 ± 15[b]	3654 ± 93[c]
	SB (cP)	1389.67 ± 24.11[a]	1736 ± 6[b]	1526 ± 41[ac]

Values expressed are mean ± standard deviation. Different lower case superscript letters in the sample row indicate significant differences ($p < 0.05$). L*; lightness, a*; redness, b*; yellowness, *To* Onset temperature, *Tp* Peak temperature, *Tc* Conclusion temperature, *ΔH* enthalpy for starch melting, *PT* Pasting temperature, *PV* Peak viscosity, *TV* Trough viscosity, *BD* Breakdown viscosity, *FV* Final viscosity, *SB* setback viscosity

Table 3 Textural properties of grass jelly formulating with different starches

Sample name	Hardness (N)	Cohesiveness	Springiness	Gumminess	Chewiness (mJ)
Potato starch grass jelly	37.67 ± 5.62^{de}	0.54 ± 0.04^{ab}	2.91 ± 0.19^{ab}	20.10 ± 2.17^{fg}	0.57 ± 0.04^{fgh}
Pea starch grass jelly	91.50 ± 6.38^{a}	0.58 ± 0.03^{a}	3.25 ± 0.05^{ab}	52.97 ± 1.20^{a}	1.69 ± 0.03^{a}
Mung bean starch grass jelly	65.50 ± 3.12^{bc}	0.60 ± 0.03^{a}	3.09 ± 0.11^{ab}	39.23 ± 1.71^{bc}	1.19 ± 0.06^{cd}
Corn starch grass jelly	66.17 ± 7.09^{bc}	0.60 ± 0.03^{a}	3.85 ± 1.28^{a}	40.00 ± 3.89^{bc}	1.49 ± 0.40^{ab}
Wheat starch grass jelly	73.00 ± 2.12^{b}	0.50 ± 0.03^{abc}	2.91 ± 0.05^{ab}	37.40 ± 2.97^{cd}	1.07 ± 0.11^{de}
Chestnut starch grass jelly	27.00 ± 2.65^{e}	0.20 ± 0.03^{f}	1.53 ± 0.13^{c}	5.40 ± 0.98^{i}	0.08 ± 0.03^{j}
Rice starch grass jelly	29.00 ± 3.77^{e}	0.15 ± 0.03^{f}	1.03 ± 0.20^{c}	4.50 ± 1.51^{i}	0.05 ± 0.02^{j}
Lotus root starch grass jelly	46.83 ± 2.36^{d}	0.61 ± 0.26^{a}	2.73 ± 0.05^{b}	28.50 ± 0.53^{e}	0.76 ± 0.01^{fg}
Sweet potato starch grass jelly	59.83 ± 4.48^{c}	0.41 ± 0.09^{cd}	2.43 ± 0.33^{b}	24.73 ± 5.84^{ef}	0.60 ± 0.21^{fgh}
Canna starch grass jelly	73.33 ± 5.35^{b}	0.60 ± 0.04^{a}	3.17 ± 0.11^{ab}	43.80 ± 2.42^{g}	1.36 ± 0.12^{bc}
Tapioca starch grass jelly	35.00 ± 1.80^{e}	0.46 ± 0.02^{bc}	2.40 ± 0.11^{b}	16.13 ± 0.81^{h}	0.38 ± 0.04^{hi}
Kudzu root starch grass jelly	59.5 ± 9.90^{c}	0.34 ± 0.09^{de}	2.43 ± 0.33^{b}	17.40 ± 2.12^{h}	0.40 ± 0.11^{hi}
Water chestnut starch grass jelly	73.17 ± 2.25^{b}	0.46 ± 0.15^{bc}	2.67 ± 0.04^{b}	33.40 ± 0.70^{d}	0.88 ± 0.02^{ef}
Chinese yam starch grass jelly	33.17 ± 3.33^{e}	0.30 ± 0.01^{e}	1.51 ± 0.48^{c}	9.90 ± 1.39^{h}	0.15 ± 0.07^{ij}

Mean ± SD ($n = 3$) is reported; different lower case superscript letters in the sample row indicate significant differences ($p < 0.05$)

(2325 ± 45 cP) and SB of kudzu root starch (1736 ± 6 cP), respectively.

Textural properties of grass jelly formulated with different starches

The texture properties of grass jelly samples such as hardness, cohesiveness, springiness, gumminess, and chewiness were analyzed by employing a texture analyzer after two cycles. The data regarding the textural properties of 14 different grass jelly samples are shown in Table 3. The grass jelly formulated with pea starch presented 3.39-, 11.77- and 33.80-fold higher values for hardness, gumminess, and chewiness compared to the hardness value of chestnut starch grass jelly (27.00 ± 2.65 N) and, gumminess (4.50 ± 1.51 N) and chewiness (0.05 ± 0.02 mJ) values of rice starch grass jelly, respectively. The grass jelly prepared using canna starch (73.33 ± 5.35 N) and water chestnut starch (73.17 ± 2.25 N) presented the second highest value for hardness. Whereas, the second highest value for gumminess (43.80 ± 2.42) and chewiness (1.49 ± 0.40 mJ) was observed in case of grass jellies prepared using canna starch and corn starch, respectively. The rice starch-based grass jelly exhibited 3.74- and 4.07-fold lowest value for cohesiveness and springiness compared to cohesiveness of lotus root starch grass jelly (0.61 ± 0.26) and springiness of corn starch-based grass jelly (3.85 ± 1.28), respectively. The second lowest values for cohesiveness (0.20 ± 0.03) and springiness (1.53 ± 0.13) were observed in case of chestnut-based grass jelly.

Sensory properties of grass jelly formulated with different starches

The sensory parameters namely appearance, texture, flavor, and overall acceptability of grass jelly samples on a scale of 1–9 are shown in Table 4. Wheat starch grass jelly presented the highest value for appearance which was 1.84-fold higher than the appearance value of pea grass jelly which exhibited the lowest score (3.1 ± 1.45). The second highest value for appearance (5.0 ± 1.94^{ab}) was recorded in case of rice starch-based grass jelly. The grass jelly formulated with Chinese yam starch exhibited 2.69-, 2.09- and 2.34-fold higher scores for texture, flavor, and overall acceptability compared to the texture (2.6 ± 1.35), flavor (3.2 ± 1.48), and overall acceptability (2.9 ± 1.37) of canna starch grass jelly, respectively. The grass jelly formulated with wheat starch exhibited second highest values for texture (6.4 ± 1.17), flavor (6.2 ± 1.03), and overall acceptability (6.6 ± 1.35).

The rubbery level score for grass jelly samples ranged from 1 to 7, and data for samples (1 to 14) are also shown in Table 4. Grass jelly formulated with Chinese yam starch presented a 3.36-fold lower score for rubbery level compared to canna starch-based grass jelly which exhibited the highest value for rubbery level (4.7 ± 1.06) compared to other samples. The second highest values (4.1 ± 0.74 and 4.1 ± 0.57) for rubbery level were observed in pea starch grass jelly and mung bean starch jelly. Whereas, the second lowest value (1.5 ± 0.71) was observed in case of chestnut starch grass jelly. In the case of preference ranking, wheat grass jelly ranked first among all the samples, while grass jelly made with canna starch scored the lowest rank.

Table 4 Sensory properties of grass jelly formulating with different starches

Sample name	Appearance	Texture	Flavor	Overall acceptability	Rubbery level	Preference ranking
Potato starch grass jelly	3.9 ± 1.29^{ab}	3.9 ± 1.20^{cde}	4.2 ± 0.92^{bcd}	4.3 ± 0.68^{cde}	3.9 ± 0.99^{ab}	5.7 ± 1.83^{cde}
Pea starch grass jelly	3.1 ± 1.45^{b}	3.4 ± 1.51^{de}	4.0 ± 1.94^{bcd}	3.4 ± 1.17^{de}	4.1 ± 0.74^{ab}	4.8 ± 3.23^{de}
Mung bean starch grass jelly	3.5 ± 1.35^{ab}	3.4 ± 1.27^{de}	3.9 ± 1.52^{cd}	3.7 ± 1.06^{de}	4.1 ± 0.57^{ab}	4.5 ± 2.72^{de}
Corn starch grass jelly	3.5 ± 1.58^{ab}	4.1 ± 1.37^{cde}	4.5 ± 1.58^{bcd}	4.2 ± 1.32^{cde}	3.4 ± 0.70^{bc}	5.4 ± 3.27^{cde}
Wheat starch grass jelly	5.7 ± 1.16^{a}	6.4 ± 1.17^{ab}	6.2 ± 1.03^{ab}	6.6 ± 1.35^{ab}	1.8 ± 0.92^{de}	12.8 ± 2.10^{a}
Chestnut starch grass jelly	4.9 ± 1.60^{ab}	6.3 ± 1.49^{ab}	5.0 ± 0.94^{abcd}	6.0 ± 0.67^{abc}	1.5 ± 0.71^{e}	11.0 ± 3.09^{ab}
Rice starch grass jelly	5.0 ± 1.94^{ab}	5.1 ± 1.97^{abcd}	5.8 ± 1.93^{abc}	5.8 ± 1.61^{abc}	2.8 ± 1.14^{bcd}	10.8 ± 2.97^{ab}
Lotus root starch grass jelly	4.6 ± 1.65^{ab}	5.7 ± 1.34^{abc}	4.6 ± 1.17^{bcd}	5.9 ± 0.88^{abc}	1.9 ± 0.57^{de}	9.6 ± 4.38^{abc}
Sweet potato starch grass jelly	4.4 ± 1.90^{ab}	5.1 ± 2.03^{abcd}	5.3 ± 1.42^{abcd}	5.2 ± 1.81^{abcd}	2.4 ± 1.27^{cde}	7.3 ± 4.30^{bcde}
Canna starch grass jelly	3.1 ± 1.83^{b}	2.6 ± 1.35^{e}	3.2 ± 1.48^{d}	2.9 ± 1.37^{e}	4.7 ± 1.06^{a}	2.8 ± 2.94^{e}
Tapioca starch grass jelly	4.9 ± 1.52^{ab}	4.5 ± 1.27^{bcde}	4.4 ± 1.27^{bcd}	4.8 ± 1.14^{bcd}	3.0 ± 1.16^{bcd}	8.9 ± 2.96^{abcd}
Kudzu root starch grass jelly	4.2 ± 2.15^{ab}	4.2 ± 1.93^{cde}	4.9 ± 2.33^{abcd}	4.3 ± 2.00^{cde}	3.3 ± 1.25^{bc}	7.2 ± 4.08^{bcde}
Water chestnut starch grass jelly	4.7 ± 1.64^{ab}	4.7 ± 0.95^{bcd}	4.9 ± 1.29^{abcd}	5.0 ± 1.33^{abcd}	2.9 ± 0.99^{bcd}	9.8 ± 3.36^{abc}
Chinese yam starch grass jelly	4.9 ± 2.18^{ab}	7.0 ± 0.81^{a}	6.7 ± 1.25^{a}	6.8 ± 1.48^{a}	1.4 ± 0.52^{e}	11.6 ± 3.98^{ab}

Mean ± SD ($n = 10$) is reported; different lower case superscript letters in the sample row indicate significant differences ($p < 0.05$)

Appearance, texture, flavor, and overall acceptability parameters ranging from 1 to 9. "1" indicated "like extremely", "2" indicated "like very much", "3" indicated "like moderately", "4" indicated "like slightly", "5" indicated "neither like nor dislike", "6" indicated "dislike slightly", "7" indicated "dislike moderately", "8" indicated "dislike very much", and "9" indicated "dislike extremely". Rubbery level parameter ranging from 1 to 6. "1" indicated "not rubbery", "2" indicated "trace of rubbery", "3" indicated "slightly rubbery", "4" indicated "rubbery", "5" indicated "very rubbery", and "6" indicated "extremely rubbery". Sample ranking parameter ranging from 1 to 14 as sample preference

The microstructure of grass jelly formulated with different starches

The scanning electron micrographs of 14 grass jelly at 20 μm and 100 μm exhibit a honeycomb-like network structure as shown in Figs. 2 and 3, respectively. Mung bean starch grass jelly (c), corn starch grass jelly (d), wheat starch grass jelly (e), chestnut starch grass jelly (f), sweet potato starch grass jelly (i), and water chestnut starch grass jelly (m) presented disordered starch distribution, which represented that gelation of the grass jelly formulated with different starches was not stable and well-aligned gelation. Whereas other samples showed to have stable network structure. The reason for this observation might be uneven formulation and interaction of starch with grass jelly polysaccharides.

Color values of grass jelly formulated with different starches

The color values (L^*, a^*, b^*) of 14 grass jelly samples are shown in Table 5. Chinese yam grass jelly exhibited the highest value for L*, which was 1.39-fold higher than the L^* value of grass jelly formulated with corn starch (20.17 ± 0.06). The canna starch grass jelly and rice starch grass jelly exhibited the second highest (27.48 ± 0.02) and second lowest value (20.91 ± 0.02) for L^*. The a^* value of grass jelly prepared with sweet potato starch and tapioca starch was 1.40-fold lower than a^* value of wheat starch grass jelly (1.78 ± 0.02). The grass jelly formulated with rice starch exhibited the second highest value (1.61 ± 0.04) and lotus root starch exhibited the second lowest (1.31 ± 0.03) value for a^*. Whereas the b^* value of potato starch grass jelly was recorded as -4.56 ± 0.01 and water chestnut starch grass jelly exhibited the highest value for b^* (-2.56 ± 0.06).

Discussion

The polysaccharide from mesona herb is an acidic anionic heteropolysaccharide with a molecular weight of approximately 1.45×10^6 g/mol and is composed of glucose and galactose (molar ratio 1.38: 1.00). Mesona herb polysaccharides exhibit promising gelling behavior and rheological properties. Mesona herb polysaccharide improves the properties of different starches used during grass jelly formation through hydrogen bonds and electrostatic interaction (Ren et al., 2020). It in turn significantly influenced the textural, pasting and overall quality of formulated jellies as discussed below.

Texture profile analysis (TPA) of grass jelly formulated with different starches

Texture properties primarily include hardness, cohesiveness, springiness, gumminess, and chewiness (Wang et al., 2018a). Hardness is determined as the peak force during the first cycle. Hardness indicates the power required to compress a sample between molars (Goldner et al., 2012). Cohesiveness is the ratio of positive areas in the second compression cycle to the first, and it reflects the strength or the internal bonds present in samples

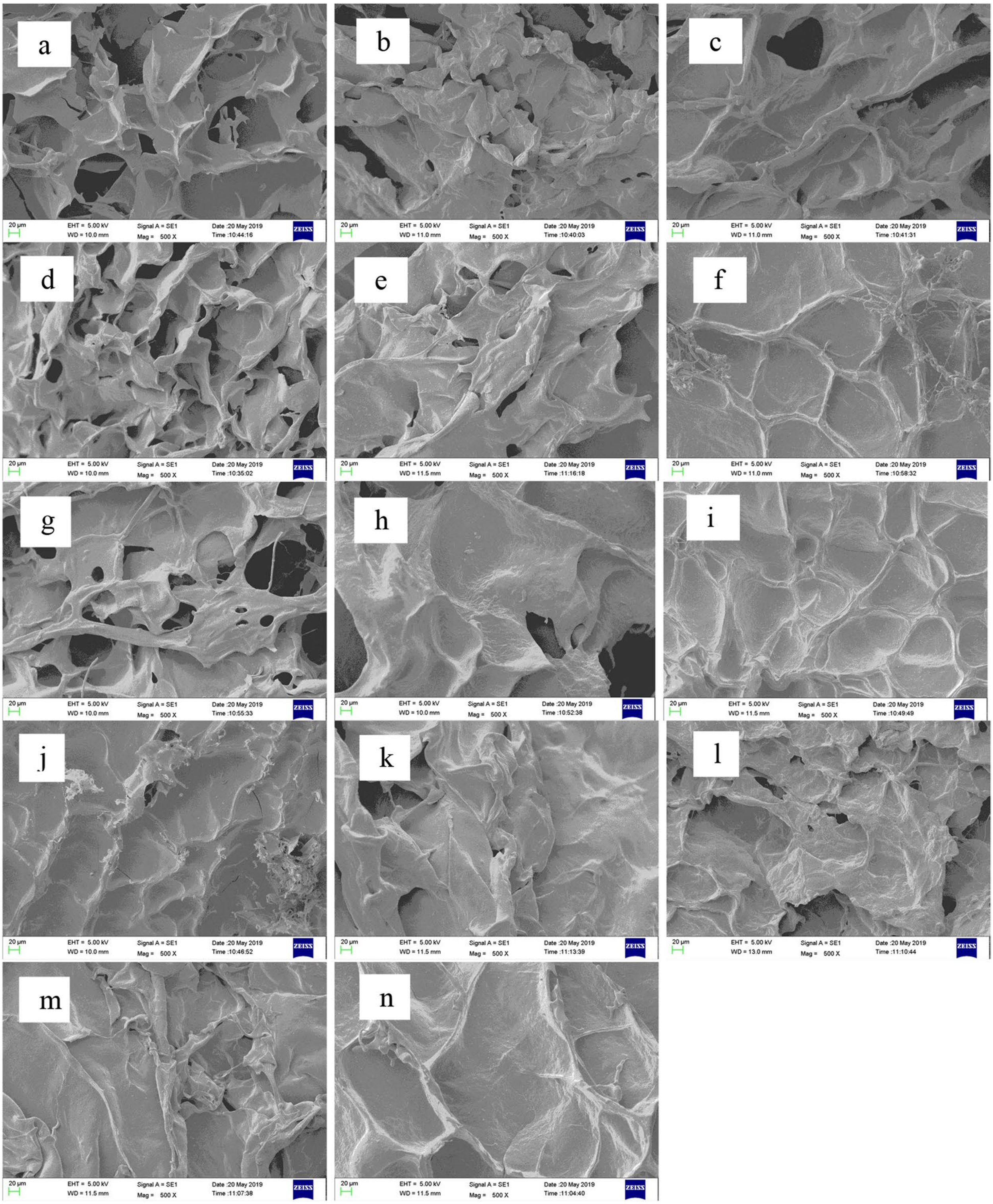


Fig. 2 SEM micrographs (500 x) under different grass jelly samples. "**a**" stands for "potato starch grass jelly", "**b**" stands for "pea starch grass jelly", "**c**" stands for "Mung bean starch grass jelly", "**d**" stands for "corn starch grass jelly", "**e**" stands for "wheat starch grass jelly", "**f**" stands for "chestnut starch grass jelly", "**g**" stands for "rice starch grass jelly", "**h**" stands for "lotus root starch grass jelly", "**i**" stands for "sweet potato starch grass jelly", "**j**" stands for "canna starch grass jelly", "**k**" stands for "tapioca starch grass jelly", "**l**" stands for "kudzu root starch grass jelly", "**m**" stands for "water chestnut starch grass jelly", "**n**" stands for "Chinese yam starch grass jelly"

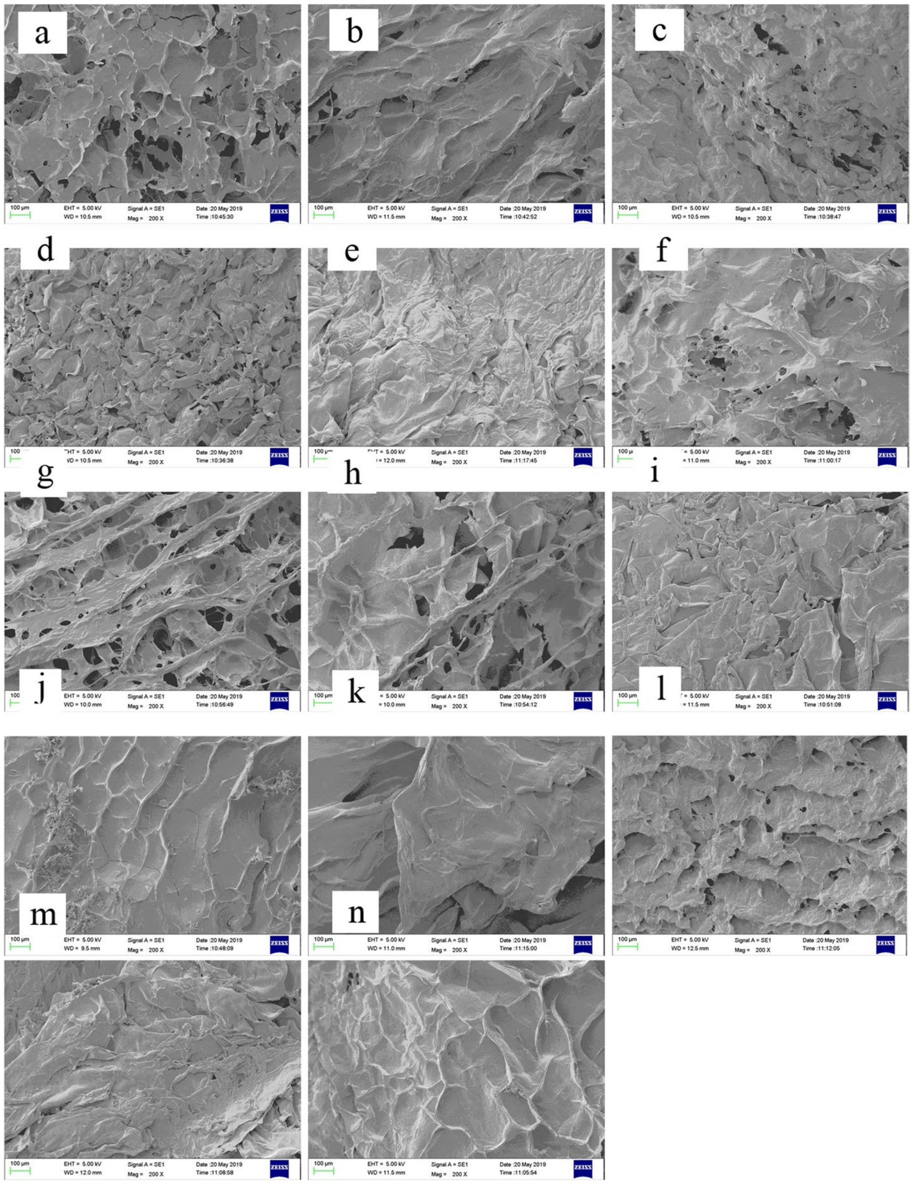


Fig. 3 SEM micrographs (200 x) under different grass jelly samples. "**a**" stands for "potato starch grass jelly", "**b**" stands for "pea starch grass jelly", "**c**" stands for "Mung bean starch grass jelly", "**d**" stands for "corn starch grass jelly", "**e**" stands for "wheat starch grass jelly", "**f**" stands for "chestnut starch grass jelly", "**g**" stands for "rice starch grass jelly", "**h**" stands for "lotus root starch grass jelly", "**i**" stands for "sweet potato starch grass jelly", "**j**" stands for "canna starch grass jelly", "**k**" stands for "tapioca starch grass jelly", "**l**" stands for "kudzu root starch grass jelly", "**m**" stands for "water chestnut starch grass jelly", "**n**" stands for "Chinese yam starch grass jelly"

(Goldner et al., 2012). Springiness is the height of a sample recovered after the first compression cycle and before the second cycle. It is also known as the ability of a food to recover its deformity after removing deforming force. The gumminess value of a product is calculated from the hard-ness*cohesiveness (Veland & Torrissen, 1999). It stands for the force required before swallowing and chewing the samples. Whereas chewiness is calculated from gumminess*springiness which stands for the energy required for chewing (Goldner et al., 2012; Veland & Torrissen, 1999).

As shown in Table 3, pea starch-based grass jelly exhibited the highest peak force compared to other samples, which means that grass jelly prepared with pea starch is harder compared to the grass jellies prepared with other starches. The pea grass jelly also presented the highest values for gumminess and chewiness. Of all the samples, mung bean grass jelly presented greater values for all the

Table 5 Color values of 14 grass jelly samples

Sample name	L^*	a^*	b^*
Potato starch grass jelly	24.88 ± 0.01^{i}	1.44 ± 0.02^{de}	-4.56 ± 0.01^{j}
Pea starch grass jelly	22.18 ± 0.04^{j}	1.55 ± 0.05^{c}	-3.69 ± 0.02^{h}
Mung bean starch grass jelly	25.51 ± 0.16^{g}	1.39 ± 0.03^{ef}	-3.77 ± 0.02^{i}
Corn starch grass jelly	20.17 ± 0.06^{n}	1.58 ± 0.05^{bc}	-3.52 ± 0.03^{ef}
Wheat starch grass jelly	21.84 ± 0.12^{k}	1.78 ± 0.02^{a}	-3.48 ± 0.01^{de}
Chestnut starch grass jelly	24.90 ± 0.01^{i}	1.49 ± 0.03^{d}	-3.42 ± 0.02^{d}
Rice starch grass jelly	20.91 ± 0.02^{m}	1.61 ± 0.04^{b}	-2.57 ± 0.03^{a}
Lotus root starch grass jelly	26.91 ± 0.06^{d}	1.31 ± 0.03^{g}	-3.47 ± 0.04^{de}
Sweet potato starch grass jelly	27.30 ± 0.10^{c}	1.27 ± 0.01^{g}	-3.59 ± 0.01^{g}
Canna starch grass jelly	27.48 ± 0.02^{b}	1.29 ± 0.01^{g}	-3.44 ± 0.00^{d}
Tapioca starch grass jelly	25.65 ± 0.09^{f}	1.27 ± 0.02^{g}	-3.20 ± 0.02^{b}
Kudzu root starch grass jelly	25.28 ± 0.02^{h}	1.33 ± 0.04^{fg}	-3.55 ± 0.02^{fg}
Water chestnut starch grass jelly	21.34 ± 0.02^{l}	1.43 ± 0.04^{de}	-2.56 ± 0.06^{a}
Chinese yam starch grass jelly	28.02 ± 0.02^{a}	1.42 ± 0.03^{e}	-3.19 ± 0.02^{b}

Mean ± SD ($n=3$) is reported; different lower case superscript letters in the sample row indicate significant differences ($p<0.05$)

indices of TPA after pea grass jelly. The pea starch mentioned to contain more amylose and less amylopectin, as well as smaller granules compared to other starch samples, thus, it is hard for pea starch to swell when interacting with hot water (Sun et al., 2014). According to previous research, mung bean and pea starch contain a higher amylose content compared to other samples investigated. Mung bean starch contains 56.3% amylose, and pea starch contains 52.0% (Liu et al., 2013). Thus, the pea starch-based grass jelly would be harder and require more energy and force to eat compared to jelly samples prepared with other starches. Amylose was mentioned as a major factor involved in the short-term development of gel structure (Sun et al., 2014). It was also mentioned that samples with higher hardness values tend to contain higher amylose content (Liu et al., 2013). In addition, an increase in the hardness value and gel strength is also attributed to the retrogradation of amylose and amylopectin as well as the interactions between the starch sample and mesona herb polysaccharide (Reddy et al., 2017). The lotus root grass jelly presented the highest value for cohesiveness and corn grass jelly exhibited the highest value for springiness. Whereas chestnut starch-based grass jelly had the lowest value for hardness and cohesiveness. Compared to peas and other starch sources, chestnut is not a popular and preferable source of starch. The chestnut grass jelly samples were observed to be soft and non-cohesive, which was an undesired and unacceptable texture for the jelly products. Besides, rice grass jelly presented the lowest values for springiness, gumminess, and chewiness compared to other samples. According to previous research, rice starch has 5 to 15% amylose content and 50 to 66% amylopectin content (Liu et al., 2013). In addition, rice starch granules are also larger than most of the other starches. This observation reflects that the amylose content in starch can strongly affect the texture properties of grass jelly samples. Besides, the granule size of starch also exhibits a significant impact on the final texture of grass jelly samples.

Sensory evaluation of grass jelly formulated with different starches

Sensory evaluation of a food product aims to measure consumers' sensory perception towards a product. Sensory evaluation plays a significant role in quality control and product development. In this study, the sensory evaluation includes the appearance, flavor, texture, acceptability evaluation, rubbery level evaluation, and the sample ranking test. The appearance, flavor, texture, and overall acceptability indices reflected the first impression of panelists towards grass jelly samples. The appearance, texture, flavor, and overall acceptability of mesona grass jellies ranges from 1 to 9, where "1" indicates "like extremely", "2" indicates "like very much", "3" presents "like moderately", "4" presents "like slightly", "5" indicates "neither like nor dislike" and "6" indicates "dislike slightly", "7" presents "dislike moderately", "8" shows "dislike very much", and "9" indicated "dislike extremely". In case of rubbery level values ranging from 1 to 6, where "1" indicates "not rubbery", "2" mentions "trace of rubbery", "3" presents "slightly rubbery", "4" presents "rubbery", "5" indicates "very rubbery", and "6" shows "extremely rubbery". In case of sample ranking values ranging from 1 to 14 present sample preference.

According to Table 4, grass jelly formulated with Chinese yam received the highest values for the texture, flavor, and overall acceptability indices. This data reflected the least preference of panelists towards Chinese yam grass jelly among all the 14 samples. The wheat and chestnut grass jelly also received higher values for texture, flavor, and overall acceptability. As per the observation of panelists, these three samples were bitterer in taste compared to other samples, and the texture was also mentioned as soft and watery which was also unacceptable. Whereas canna grass jelly obtained the lowest values for texture, flavor, and overall acceptability which revealed the high preference for canna grass jelly by all the panelists among all the samples. Some panelists commented that the Canna grass jelly was less bitter compared to other samples.

As mentioned in Table 4, the highest value (4.7) for the rubbery level was observed in case of canna grass jelly. Since "4" stands for rubbery and "5" stands for very rubbery, the sample was a bit surplus in the rubbery index. Chinese yam and chestnut grass jelly have received the lowest values for rubbery level. It showed that these two samples were too watery and soft, and not present a jelly-like texture among all the samples. The rubbery value for pea, mung bean, and potato grass jelly was close to “4” (rubbery) which were 4.1, 4.1, and 3.9, respectively. Thus, these samples can also be considered elastic with jelly-like texture.

According to Table 4, wheat, Chinese yam, and chestnut grass jelly received the highest value in ranking test while grass jelly made with canna starch obtained the lowest value (2.8) in ranking test which presents the preference of panelists towards this sample. The pea and mung bean grass jelly with values 4.8 and 4.5 in the ranking test were also preferred by panelists. Overall, grass jelly formulated with canna starch was most preferred by all panelists during sensory analysis based on all the parameters accessed.

SEM of grass jelly formulated with different starches

Untreated starch samples exhibit crystal-like structures. When starch is heated with water, the phenomenon of crystal melting and disintegrating occurs. That in turn changes the ordered structure of starch particles to disordered structures. Starch particles gradually swelled until the starch attained a sticky uniform colloidal state (Liao et al., 2014). SEM images from a previous study on morphology changes of starch during gelation under heating revealed the formation of network structure due to swelling of granules and leaching of starch chains during heating (Liu et al., 2003; Yan et al., 2021). In the present study, all samples have also presented a three-dimensional honeycomb-like network due to the swelling of starch granules and the leaching of starch chains due to heating while preparing grass jelly as shown in Fig. 1 under 500-fold magnification. However, each of the network structures exhibits slight variations. The jelly samples produced with more gelatinized starch resulted in a more closed structure with smaller pores compared to jellies produced with less gelatinized starch (Feltre et al., 2020). This finding may be attributed to the leached amylose during gelatinization that interacts with polysaccharides present in the Mesona herb. Under the magnification of 200x, in Fig. 2 a, g, h, and l, the holes in the micrographs are bigger which represents significant swelling and gelation of starch. In Fig. 2 b, f, j, k, and n, the morphology of the grass jelly seems to be smoother compared to other samples. This smooth morphology may be responsible for the smooth texture and better taste of these samples as reported in sensory analysis of samples.

Color values of grass jelly formulated with different starches

The color values of grass jelly included L^*, a^*, and b^* which indicated the lightness and saturation of sample color. As observed in Table 5, all the grass jelly samples exhibit a stable value for L^* around 20 to 30%. Among all 14 samples, Chinese yam grass jelly presented the highest value for lightness, whereas, the grass jelly prepared with corn starch exhibit the lowest value for lightness. Since L^* values for all the samples were lower than 30%, all the grass jellies appeared dark in color. The value for a^* parameter of all the grass jelly samples was positive. Among 14 samples, wheat grass jelly presented the highest value (1.78%) for a^*, whereas sweet potato grass jelly had the lowest value (1.27%). Thus, the red color of wheat starch-based grass jelly was at the highest level of saturation and the red color of grass jelly with sweet potato starch was at the lowest level of saturation. In case of b^* parameter, all the values were negative which reflected that the samples have a blue color. The water chestnut grass jelly presented the highest value (-2.56%) for b^* while the potato grass jelly exhibited the lowest value (-4.56%). Thus, the blue color of water chestnut grass jelly was at the lowest level of saturation while the blue color of potato grass jelly was at the highest level of saturation. When compared a^* and b^*, the values for both parameters were low, which showed that the grass jelly samples did not exhibit obvious red and blue color.

Conclusion

In the present study, 14 different mesona herb-based grass jellies were prepared using different starches. These grass jellies were tested and compared for their textural profile, sensory quality, morphological analysis, and color values. Overall, pea starch- and corn starch-based grass jellies formulated with pea and corn starch presented improved textural properties. The canna grass starch-based jellies were also appreciated by panelists for their texture and decent flavor. The overall acceptability of canna grass starch-based jellies was also high compared to other grass-jelly samples. All grass jelly samples exhibited a desirable glossy dark color with insignificant differences in color values among all samples. SEM analysis revealed the honeycomb network structure of jelly samples. Furthermore, the proximate composition, phytochemical profile, and health-promoting properties of these formulated grass jellies can be explored to recommend high-quality grass jelly for consumers interested in functional foods.

Supplementary Information

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Supplementary Material 1.

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Authors' contributions
SZ: Investigation, Formal analysis, Software, Data curation, Writing Original draft. MM: Investigation, Validation, Data curation, Writing original draft. BX: Conceptualization, Methodology, Supervision, Writing-Review & Editing, Project administration, Funding Acquisition.

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Data availability
Data will be available upon request.

Declarations

Ethics approval and consent to participate
There are no human subjects and experimental animal involved in this study.

Consent for publication
All authors agreed to submit this manuscript to this journal for publication.

Competing interests
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Author details
[1]Department of Life Sciences, Food Science and Technology Programme, BNU-HKBU United International College, Zhuhai 519087, Guangdong, China.

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