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Assessment of quality of Thai wheat drinking straws produced from different wheat varieties

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ABSTRACT

Wheat cultivation in Thailand has increased, especially bread wheat, durum wheat, and triticale, owing to a surge in local demand for grain and stalks to produce drinking straws. This study aimed to assess the quality of wheat drinking straws manufactured by a community enterprise in Lampang Province, Thailand, in accordance with the community product standard for plant-based straws (CPS. 1558/2020), a pertinent regulation for plant-based straws in Thailand. This study assessed the quality of three varieties of Thai wheat drinking straws: Fang 60, Durum No. 31, and Triticale No. 23. All three varieties met the necessary criteria, including their general appearance, odor, shape retention, moisture content, and microbial contamination levels, thereby confirming their adherence to the established standards in Thailand. The customer's evaluation of wheat straw regarding odor, color, shape, and suction quality revealed positive feedback. Triticale No. 23 and Fang 60 straws garnered the highest overall satisfaction ratings, closely followed by Durum No. 31 straws, which also attained high satisfaction ratings. This study demonstrates that temperate grain stalks are suitable for the manufacture of drinking straws. It also ensures customer acceptance and quality, hence guaranteeing the market potential in the future.

Keywords: drinking straws, bread wheat, durum wheat, triticale, community product standard for plant-based straws (CPS.1558/2020)

INTRODUCTION

Although plastic straws are durable and inexpensive, they represent a significant source of pollution, contributing to environmental issues and posing risks to human health and other organisms. Annually, approximately 300 million tons of plastic are manufactured, a significant portion of which is relegated to landfills or disposed of inappropriately, resulting in about 14 million tons infiltrating aquatic environments (Muneer et al., 2021; Isangedighi et al., 2020). It is anticipated to double within the next two decades (Boyle and Örmeci, 2020). An effort is underway to diminish plastic straw usage by transitioning to more eco-friendly alternatives, such as reusable stainless-steel and glass straws or disposable and biodegradable options, including paper and plant-based straws (Qiu et al., 2022).

To encourage straw users to choose more environmentally sustainable alternatives, these straws must be competitively comparable to plastic straws. They must be economical, adhere to hygiene and safety standards, exhibit durability, show low water absorption, and feature heat resistance. Concurrently, manufacturers must ensure market viability, encompassing sufficient production capacity, reduced costs, and economic value. The wheat stem, a byproduct of wheat farming, shows potential as an alternative drinking straw, as it satisfies most of the recommended criteria (Qiu et al., 2022; Tarani and Chrissafis, 2024).

Wheat including bread wheat (*Triticum aestivum* L.), durum or macaroni wheat (*Triticum turgidum* L. var. durum), and triticale (X *Triticosecale* Wittmack), a hybrid between wheat (*Triticum* ssp.) and rye (*Secale* ssp.) is one of temperate crop introduced into Thailand as alternative cash crops in highland areas where the average temperatures are lower and more suitable for its growth and development (Thai Encyclopedia Project for Youth Volume 17, 1993; Chaiwongsar, 2023). Recently, domestic wheat cultivation has garnered interest due to the insecurity of wheat imports and the rising demand from niche markets such as artisan bakeries, wheat grass juice producers, malt manufacturers, and florists. These markets favor domestic grain or seed because of the complexities associated with the import procedure. To enhance wheat growing in Thailand, incentives such as using wheat straw should be established to enable farmers to increase their revenue. Numerous reports indicate the applications of wheat straw, including cellulosic ethanol production (Ruan et al., 2019), fiber (Zhang et al., 2022), particle board (Loh and Nguyen, 2023), and drinking straws (Tarani and Chrissafis, 2024). Nevertheless, this research has only been examined in Thailand.

As mentioned above, wheat stems can effectively replace conventional plastic drinking straws. It is an entirely organic substance that will decompose spontaneously. Consequently, wheat straws obtained from agricultural production necessitate no energy, and like a plant, it absorbs CO_2 throughout the stem elongation phase, with no chemicals utilized in the manufacturing process. Despite stringent European and national legislation governing materials in contact with food, there are no European regulations pertaining to the physicochemical qualities of wheat straw (Tarani and Chrissafis, 2024). In Thailand, there exists a standard governing the production of plant-based straws, known as the Community Product Standards for Plant-Based Straws (CPS.1558/2020). This standard mandates that plant-based straws, manufactured as a community product, must meet criteria including general characteristics, odor, shape retention, moisture content, microbial contamination, and packaging (Ministry of Industry, 2020). Therefore, this study aimed to evaluate the quality of wheat straw produced from prevalent types in Thailand: bread wheat (Fang 60), durum wheat (Durum No. 31), and triticale (Triticale No. 23), by a community enterprise in Lampang province. The criteria of the standard, the function of the straw, and user satisfaction were employed to evaluate the quality of the Thai wheat straws.

MATERIALS AND METHODS

Sample collection

The drinking straws used in the experiment were composed of three wheat varieties: bread wheat (Fang 60), durum wheat (Durum No. 31), and triticale (Triticale No. 23). These kinds of wheat were predominantly cultivated in Samoeng District, Chiang Mai Province, under the oversight of the Samoeng Rice Research Center, located in Samoeng District, Chiang Mai Province. The wheat stems were processed through cleaning with micro-nano bubbles water supplied with ozone, cutting, and sterilization with UV light into drinking straws by the organic agricultural community enterprise in Ban Cham Bon, Ton Thong Chai Subdistrict, Mueang District, Lampang Province. The processed straws measured 20 cm long, with a diameter ranging from 4–7 mm, and were packaged in 100 pieces. The straw samples were taken randomly from three distinct packages.

Quality assessment

Straw samples obtained randomly were evaluated in accordance with the Community Product Standards for Plant-Based Straws (CPS.1558/2020) for the desirable characteristics and functions (Ministry of Industry, 2020), as detailed below:

Appearance. Samples were assessed via visual inspection for undesirable straw attributes, including fractures, foreign objects, rough or sharp edges at both extremities and discrepancies in shape and size. The dimensions, including length, outer diameter, inner diameter, and thickness of the straw were evaluated.

Odor. Samples were evaluated by five trained olfactory evaluators using olfactory assessment of undesirable scents, including musty, rancid, and spoilt odors, before water immersion and subsequently evaluated following a 30-min soak at temperatures of 100, 25, and 4°C.

Shape retention. Samples were immersed in distilled water at a temperature of approximately 25 ± 2°C to a depth of not less than 1/2 but not more than 3/4 of the tube length for 5 and 120 min, according to the recommendation from the CPS.1558/2020. The shape alteration and defects, including leakage, cracks, and shapes, were visually inspected.

Function performance. For sucking quality, an automatic pipette controller was used to pull water at temperatures of 100, 25, and 4°C through the straws. After suction, water was held in the straw tube for 5 min. The volume of pulled and retained water, along with the expected volume, was assessed to illustrate the performance of the straws. This assessment was conducted on straw samples used in shape retention evaluation. The undesired tastes were also evaluated for straw before and after water submersion.

Moisture content. The straws were segmented into diminutive fragments measuring around 0.5 cm. The samples were measured prior to and after drying. The samples were placed in a container with a known moisture content and subjected to drying in a hot air oven at 105°C for 24 h. The weight was utilized to determine the moisture content in the samples (AOAC, 1990) by using the following formula:

$$\mathrm{MC}\ (\%) = \frac{\mathrm{Wm} - \mathrm{Wd}}{\mathrm{Wm}} \times 100$$

Where MC is the moisture content (dry basis), Wm is the weight of the sample before the drying process, and Wd is the weight of the sample after the drying process.

Microorganism detection. Samples were cut into small pieces, approximately 0.5 cm. Potential microorganisms were extracted by mixing cut samples with distilled water in a 1:10 (w/v) ratio and shaking for about 1 min. The extract was analyzed for microorganisms as follows:

- The total bacterial count was assessed by pipetting 0.1 mL of the extract onto a solid nutrient agar (NA) plate, distributing the extract evenly across the surface, and incubation at 37°C for 24 h. The colonies on the plate were enumerated, and the total bacterial count (CFU/unit) was determined according to Sperber et al (2015).

- *Staphylococcus aureus* was identified by applying 0.1 mL of extract onto a solid trypticase soy broth (TSB) plate supplemented with 10% NaCl and 1% sodium pyruvate, dispersing the extract across the surface, incubating at 37°C for 24 h, enumerating the colonies on the plate, and calculating the concentration of *Staphylococcus aureus* (CFU/unit) in accordance with U.S. Food and Drug Administration (2019) guidelines.

- *Salmonella* spp. was identified by pipetting 0.1 mL of the extract onto a solid xylose lysine deoxycholate agar (XLD agar) plate, distributing the extract evenly, incubating at 37°C for 24 h, and enumerating the colonies on the plate to calculate the concentration of *Salmonella* spp. (CFU/unit) (ISO 6579-1:2017, 2017).

- Fungal quantification was performed by pipetting 0.1 mL of the extract onto a solid potato dextrose agar (PDA) plate, spreading the extract over the surface, incubating at 37°C for 24 h, and counting the colonies on the plate and calculating the fungal count (CFU/unit) (Sperber et al., 2015).

Consumer satisfaction survey

A comprehensive evaluation of consumer satisfaction regarding wheat straws was conducted with 100 participants utilizing a 5-point hedonic scale, where an average score of 1.00–1.80 indicates minimal satisfaction, 1.81–2.60 denotes slight satisfaction, 2.61–3.40 reflects moderate satisfaction, 3.41–4.20 signifies high satisfaction, and 4.21–5.00 represents maximal satisfaction (Likert, 1967). In this consumer test, participants utilized wheat straw with room-temperature bottled water and offered feedback on odor, color, cleanliness, shape, suction quality, and overall satisfaction.

Statistical analysis

The experimental results were analyzed using analysis of variance (ANOVA). Data were analyzed using a Statistical software program (SPSS 16.0), and the difference in means was analyzed using Duncan's new multiple range test with a significant level of $P \leq 0.05$.

Ethics declarations

This study has received approval from the Human Research Ethics Committee at Rajamangala University of Technology Lanna, in accordance with the principles of the Declaration of Helsinki and the International Conference on Harmonization in Good Clinical Practice (ICH-GCP) guidelines, reference number RMUTL-IRB 052/2022.

RESULTS AND DISCUSSION

Quality of Thai wheat drinking straws

Currently, Thailand has a regulation related to biodegradable straws, which is the Community Product Standard for Plant-Based Straws (CPS.1558/2020) under the supervision of the Ministry of Industry. Therefore, Thai wheat drinking straws were tested for desirable characteristics and function based on this standard.

Appearance. Visual inspection revealed no defects, such as cracks, breakage, foreign objects, unsmooth ends, or sharp edges, in the three types of wheat straws: Fang 60, Durum No.31, and Triticale No.23 (Table 1, Figure 1). Dimension measurements, encompassing length, diameter, and thickness of each straw type, revealed no significant differences within the same type of straws, indicating uniformity in straw dimensions. Nonetheless, a comparison of straw types revealed substantial differences in outer diameter, inner diameter, and thickness ($P < 0.01$) (Table 2). Triticale No. 23 straw exhibited the greatest value across all parameters. Although Fang 60 straw exhibits a smaller outer diameter compared to Triticale No. 23 straw, it possesses the maximum inner diameter, akin to Triticale No. 23 straw, due to its minimal wall thickness (Table 2).

Odor. The olfactory assessments indicated that all three straw types had no unpleasant odor before or after immersion in water at temperatures of 100, 25, and 4°C (Table 3). However, when straws were submerged in hot water, a faint straw odor was detected, which was attributed to the organic compound coumarin (Hussain et al., 2019) and the chemical byproduct of lignin decomposition in plants, which produced an aroma akin to dry straw (Guggenberger et al., 2023). This straw odor did not hinder usage, and aligned with the user satisfaction assessment results, which the participants felt that this odor positively influenced their experience by imparting a sense of nature and not interfering with the beverage's taste.

Table 1. Quality of drinking straw samples derived from different wheat stalks according to abnormality regulation under the CPS.1558/2020

Straw types	Parameters for abnormalities				
	Cracks	Foreign materials	Scrap Materials	Unsmooth ends	Sharp edges
Fang 60	✓	✓	✓	✓	✓
Durum No.31	✓	✓	✓	✓	✓
Triticale No.23	✓	✓	✓	✓	✓

✓ = the samples have met or exceeded the required standard.

Table 2. Dimensions of drinking straw samples derived from different wheat stalks

Straw types	Length (mm)	Outer diameter (mm)	Inner diameter (mm)	Thickness (mm)
Fang 60	200 ± 0.12	4.34 ± 0.32^{b}	3.42 ± 0.25^{a}	0.43 ± 0.20^{b}
Durum No.31	200 ± 0.14	4.38 ± 0.38^{b}	3.23 ± 0.28^{b}	0.58 ± 0.22^{a}
Triticale No.23	200 ± 0.14	4.51 ± 0.30^{a}	3.38 ± 0.25^{a}	0.56 ± 0.21^{a}
F-test	ns	**	**	**
CV (%)	0.67	7.56	7.81	6.28

^{ab}Different superscripts in the same column indicate highly significant differences ($P < 0.01$); ns = not significant; ** $P < 0.01$.

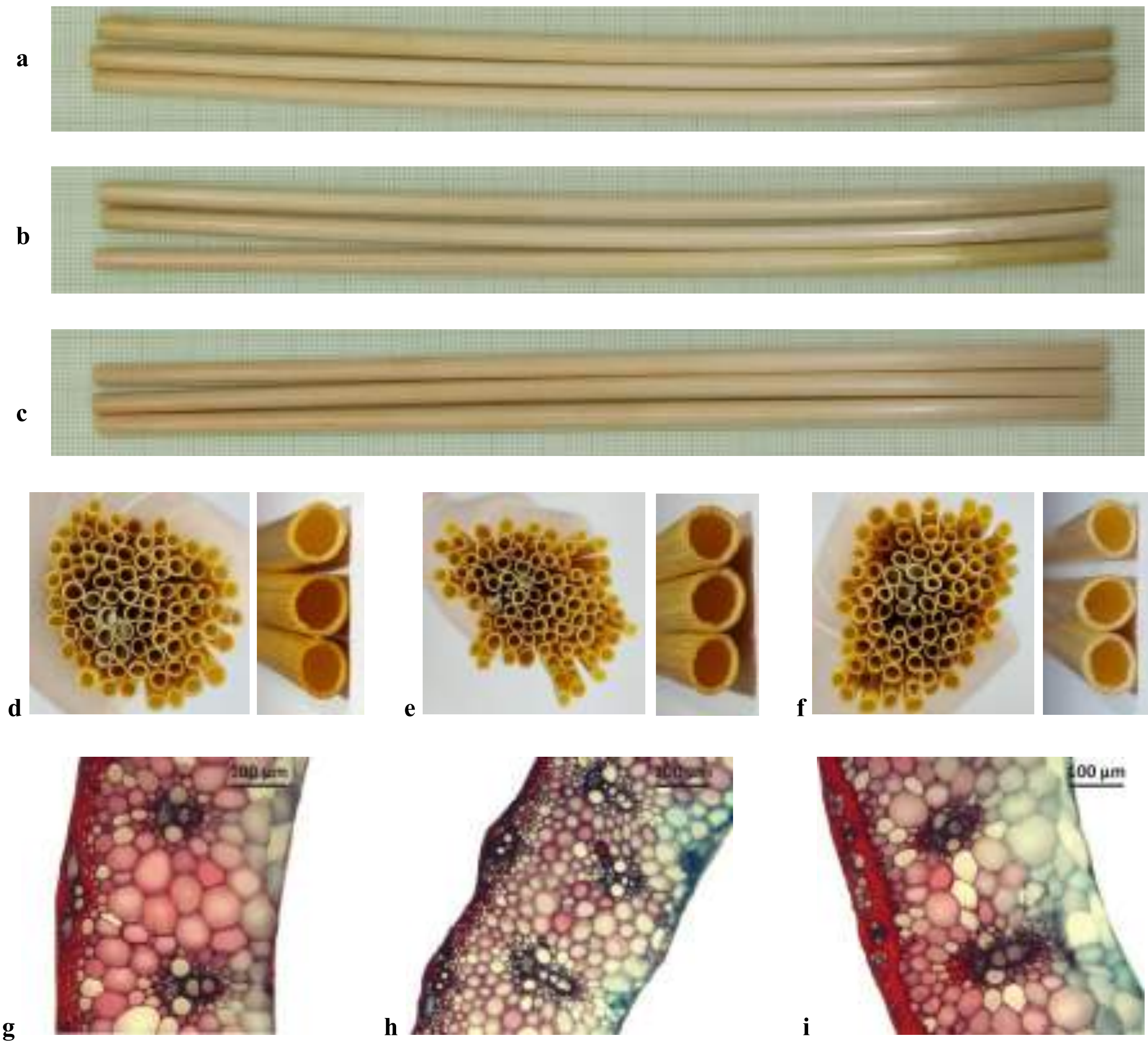

Figure 1. Drinking straws made from wheat stalks **(a-c)**: **(a)** Fang 60, **(b)** Durum No. 31, and **(c)** Triticale No. 23. Smooth ends of drinking straws **(d-f)**: **(d)** Fang 60, **(e)** Durum No. 31, and **(f)** Triticale No. 23. Cross sections of drinking straws **(g-i): (g)** Fang 60, **(h)** Durum No. 31, and **(i)** Triticale No. 23. (scale bar = 100 µm).

Table 3. Quality of drinking straw samples derived from different wheat stalks according to unpleasant scents requirements before and after being immersed in water at various temperatures according to the CPS.1558/2020

Straw Types	Parameters for abnormalities			
	Before immersion in water	After immersion in water		
		Room temperature (25°C)	Hot (100°C)	Cold (4°C)
Fang 60	✓	✓	✓	✓
Durum No.31	✓	✓	✓	✓
Triticale No.23	✓	✓	✓	✓

✓ = the sample has met or exceeded the required standard.

Shape retention and function performance. The shape retention assessment revealed no anomalies, including leakage, cracks, or shape alteration, after immersing the straws in water for 5 and 120 min (Table 4). Furthermore, during the assessment of function performance, the evaluators perceived no alteration in sucking quality or flavor interference when tested with drinking water at different temperatures (Table 4). The results indicated that all three types of wheat straw exhibited stability, likely due to their low water absorption and heat resistance properties (Jiang et al., 2020; Tarani and Chrissafis, 2024). The resistance of wheat straws to liquid contact is a significant characteristic that reflects the quality of drinking straws (Yang et al., 2022), positioning wheat straws as a competitive alternative to other drinking straw options. Li et al. (2023) stated that cracks and deformations were seen when plastic and paper straws were immersed in hot water. Furthermore, paper straws exhibited substantial water absorption during use, resulting in considerable swelling and shrinkage, a reduction in structural integrity, bending or fraying when stirring drinks, and heightened liquid absorption with rising liquid temperatures (Tarani and Chrissafis, 2024; Gutierrez et al., 2019; Kwak et al., 2023; Luan et al., 2023; Ghazali et al., 2021). Additionally, Jonsson et al. (2021) indicated that paper straws and those produced from starch derived from corn, wheat, pasta, and rice produced an undesirable taste and unfavorable mouthfeel.

Moisture content. It is essential to sustain moisture levels within this range, as elevated moisture content can facilitate the proliferation of microbes (Zhang et al., 2023). The moisture content of the tested straws, varying from 5.91–7.82%, remained below the stipulated requirement of 10% by weight, indicating that wheat straw can be desiccated to eliminate moisture levels within the norm, hence ensuring protection against microbial contamination.

Microorganisms. Microbial contamination in agricultural products that contact the digestive system may induce toxicity and health hazards (Hamad, 2012). The microbes frequently identified in these products include *Staphylococcus aureus*, a pathogenic and virulent bacterium, and *Salmonella* spp., which is responsible for gastritis, enteritis, bloodstream infections, and other severe systemic diseases (Larkin et al., 2009; Bibi et al., 2015; Ehuwa et al., 2021). In addition to bacterial contamination, certain fungi that generate poisonous mycotoxins pose health risks and may be present in agricultural products like grains and straw (Gozzi et al., 2024). Some plant-based straws rich in carbohydrates and high water absorption capacity, such as bamboo straws, are susceptible to fungi, bacteria, and pests due to their high starch content (Cheng et al., 2013; Wu et al., 2019. Consequently, the prevention of microbial contamination through suitable production procedures, including sanitizing and drying, as well as the regulation of parameters influencing microbial development, such as moisture content, is essential. The microbial quantity test findings indicated that all three types of straws met the standard parameters. The total bacterial count was below 10 CFU/unit, and *Staphylococcus aureus*, *Salmonella* spp., and fungi were absent (Table 6), indicating that wheat straws can be processed and managed in a manner that inhibits microbial growth, thereby minimizing microbial contamination in accordance with the standard.

Table 4. Quality of drinking straw samples made from wheat stalks for detected abnormalities during shape retention and function performance testing according to CPS.1558/2020

Straw types	Parameters for abnormalities														
	Leakage			Crack			Shape			Suction quality			Undesired tastes		
	Before immersion	Immersion (min)		Before immersion	Immersion (min)		Before immersion	Immersion (min)		Before immersion	Immersion (min)		Before immersion	Immersion (min)	
		5	120		5	120		5	120		5	120		5	120
Fang 60	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Durum No.31	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Triticale No.23	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

✓ = the samples have met or exceeded the required standard.

Table 5. Moisture content of drinking straw samples made from wheat stems

Different temperate cereal straw varieties	Moisture content (%)
Fang 60	5.91 ± 0.23^{b}
Durum No.31	6.28 ± 0.07^{a}
Triticale No.23	6.50 ± 0.08^{a}
F-test	**
CV (%)	2.32

[ab]Different superscripts in the same column indicate highly significant differences ($P < 0.01$).

Table 6. Microbial content found in various types of temperate crop stalks

Straw Types	Total bacteria count (CFU/sample)	*Staphylococcus aureus* (CFU/Sample)	*Salmonella* spp. (CFU/sample)	Fungi count (CFU/sample)
Fang 60	<10	Not detected	Not detected	Not detected
Durum No.31	<10	Not detected	Not detected	Not detected
Triticale No.23	<10	Not detected	Not detected	Not detected

The results of testing straws made from temperate crops such as wheat found that all three types of straws passed the criteria set by the Community Product Standards for Plant-Base d Straws (CPS.1558/2020) in terms of the required characteristics (Table 7), including the general characteristics of the straws: they must not have cracks, breaks, foreign objects, or impurities that affect the use, both ends are smooth, there are no sharp edges, and they have a similar shape and size. No unpleasant odor. Straws must maintain their shape after immersion in water, function normally, have no leaks, cracks, or abnormalities affecting the use, and have no taste after sipping water. The moisture content of the straw sample does not exceed 10% by weight. The amount of microorganisms found passes the criteria specified by the standard.

Table 7. Summary of the test findings for drinking straw samples made from wheat stalks following CPS.1558/2020

Straw Types	General characteristics	Odor	Shape retention	Moisture	Microorganisms
Fang 60	✓	✓	✓	✓	✓
Durum No.31	✓	✓	✓	✓	✓
Triticale No.23	✓	✓	✓	✓	✓

✓ = the samples have met or exceeded the required standard.

Consumer survey and feedback

One hundred people participated in this survey, with all questionnaires collected after customer testing. The poll encompassed significant aspects influencing the consumer's purchasing decision, specifically odor, color, shape, and suction quality. Prior studies suggested that the color of the straw could influence the sensory attributes of a beverage's taste and scent (Akiyama et al., 2012). The perception of consumption was also impacted by straw diameter; straws with thin walls exert a greater effect than straws with thicker walls (Lin et al., 2013).

The tactile and visual texture also influences emotions and choices (Biggs et al., 2016). The survey results revealed no significant differences in satisfaction scores for the three varieties of wheat straws for odor, color, cleanliness, and sucking quality. The responders indicated the greatest satisfaction with the qualities of color and cleanliness. Several participants provided additional feedback, highlighting that the color of wheat straw represents its natural quality, and they expressed astonishment at the straws' cleanliness. Triticale No. 23 got the best score for overall satisfaction scoring, attributed to its size. According to Table 2, Triticale No. 23 straw possesses the largest outer and inner diameters, rendering it more favorable to customers. Nonetheless, Fang 60 and Durum No. 31 Triticale No. 23 garnered positive responses from the participants. Triticale No. 23 and Fang 60 straws had the highest overall satisfaction ratings, followed closely by Durum No. 31 straws, which also garnered high satisfaction ratings. The survey suggested that Thai wheat straws can compete in a market of eco-friendly products.

Table 8. Summary of the test findings for drinking straw samples made from wheat stalks following CPS.1558/2020

Straw Types	Odor	Color	Cleanliness	Shape	Suction quality	Overall satisfaction
Fang 60	4.17 ± 0.65	4.45 ± 0.69	4.66 ± 0.50	3.92 ± 0.69^{b}	4.18 ± 0.72	4.21 ± 0.74^{b}
Durum No.31	4.00 ± 0.75	4.46 ± 0.66	4.73 ± 0.45	3.81 ± 0.72^{b}	4.15 ± 0.73	4.20 ± 0.78^{b}
Triticale No.23	4.16 ± 0.73	4.42 ± 0.64	4.74 ± 0.44	4.20 ± 0.72^{a}	4.33 ± 0.73	4.52 ± 0.66^{a}
F-test	ns	ns	ns	**	ns	**
CV (%)	17.38	14.89	9.80	17.92	22.85	16.89

[ab]Different superscripts in the same column indicate highly significant differences ($P < 0.01$); ns = not significant; ** $P < 0.01$.

CONCLUSIONS

In response to the issue of plastic straw waste, there is a significant demand for alternative straws with minimal or no adverse environmental effects. This study evaluated the quality of three varieties of Thai wheat drinking straws: Fang 60, Durum No. 31, and Triticale No. 23 manufactured by a community enterprise in Lampang, Thailand. The wheat straws were evaluated in accordance with the community product standard for plant-based straws (CPS. 1558/2020). All three varieties of straws satisfied the requisite characteristics, including general appearance, odor, shape retention, moisture content, and microbial levels, confirming their compliance with the established standards in Thailand (Table 7). The customer's testing indicated that the straws elicited favorable responses. Triticale No. 23 and Fang 60 straws received the greatest overall satisfaction ratings, closely followed by Durum No. 31 straws, which also achieved high satisfaction ratings. The results indicate that wheat straw has market potential and warrant additional investigation into scaling production and the economic implications of substituting plastic straws with wheat straws.

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