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Consumer Acceptability and Flavor Attributes of Black Walnut Syrup: Tapping into a Climate-resilient and Profitable Alternative to Traditional Syrups

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Abstract. **Black walnut (*Juglans nigra* L.) is a climate-resilient species that presents underexplored opportunities for horticultural applications, including tapping for syrup production. This study evaluated consumer liking of black walnut syrup and characterized consumer descriptions of its flavor compared with maple syrup. Five syrups were evaluated: two grade A maple syrups (Maple1 and Maple2), a commercial black walnut syrup (PBW_commercial), two locally produced black walnut syrups (PBW_UMN1 and PBW_UMN2), and a black walnut–infused syrup (BW_infused). Participants (n = 106) evaluated six syrup samples and rated them on attributes such as color, overall liking, flavor liking, and the intensity of specific flavors (e.g., caramel, nutty, woody, maple, burnt, bitter). Statistical analyses revealed differences among syrups for all attributes. Darker syrups (PBW_commercial, PBW_UMN2) exhibited stronger woody, burnt, and bitter flavors, while lighter syrups (PBW_UMN1, BW_infused) had milder profiles. PBW_UMN2 closely resembled Maple2 for most attributes, while PBW_commercial differed, with lower overall liking and caramel scores and higher nutty, woody, burnt, and bitter attributes. Principal component analysis indicated that flavor liking and overall liking were negatively correlated with bitter and burnt flavors but positively correlated with maple and caramel flavors. Multiple linear regression models showed that caramel and maple flavors positively influenced liking, while bitterness negatively affected it. The blend of familiar flavors and distinctive black walnut characteristics indicated that PBW_UMN2 could be as liked as maple syrup. This study highlights the market potential of black walnut syrup, suggesting that balancing caramel, woodiness, and nuttiness while minimizing bitterness can enhance consumer acceptability.**

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Black walnut (*Juglans nigra* L., Juglandaceae) is a long-lived perennial tree species native to North America. It is widely distributed across the United States with extensive wild and cultivated stands (Randolph et al. 2013) ranging from western Vermont and Massachusetts through southern Ontario, central Michigan, and southeastern Minnesota, westward to eastern Nebraska and Kansas, and southward to northern Florida and eastern Texas (Dirr 2009). As a landscape tree, its use is restrictive due to allelopathic chemicals from the nut hulls permeating soils beneath the canopy (Jose 2002). Traditionally valued for its nuts and high-quality timber (McKenna and Coggeshall 2018; Miller and Chambers 2013), black walnut has been the focus of cultivar development since the late 19th century, with 'Thomas' introduced in 1881 (Victory et al. 2004). Since then, breeders and growers have named more than 750 cultivars, most selected for nut production, kernel quality, or timber value (Reid et al. 1990). Widely recognized cultivars include Thomas, Emma K, and Sparrow, known for cracking quality and flavor (Rink 1988), while recent releases such as UMCA® 'Hickman' (Coggeshall et al. 2025) emphasize improved nut quality, yield, and disease resistance. A new economic opportunity for its application lies within its sap, which can be harvested to produce syrup (Naughton et al. 2006) with culinary uses similar to traditional maple syrup.

Currently, sugar maples (*Acer saccharum* Marshall) are the primary trees used for commercial sugaring to produce maple syrup. However, climate change might affect the future growing range of maple and the ecoregions, challenging the current scope of viable production regions within the United States for sugaring, likely resulting in decreases in the overall volume produced (Rapp et al. 2019). The climatic shifts anticipated could also lead to changes in maple sap yield, quality, and flavor characteristics (McHugh et al. 2024). As sugar maple production regions shift and syrup output potentially declines, exploring alternative tree species with a wider range of climate adaptability, such as black walnut, for syrup production becomes increasingly important. These alternative syrups could diversify and stabilize the syrup industry, providing resilience against environmental changes and offering unique flavor profiles that appeal to niche markets (Carpio and Lange 2015).

Black walnut syrup could be a profitable addition to existing maple syrup operations, offering producers a way to diversify their product lines. Although the species have distinct morphophysiological characteristics, the equipment and methodology for harvesting and processing sap into syrup are similar. Therefore, incorporating black walnut into sugaring operations can open new revenue streams, particularly on farms where black walnut trees are present but underutilized. In the past, it was commonly believed that sap yield and sugar concentration of black walnuts would be lower than those of maple. However, recent research suggests that, depending on the genotype (cultivars and breeding lines), the sugar concentration of black walnut sap might even surpass that of maple; with the use of a vacuum pump, their sap yields are likely comparable (Pollock 2024). In terms of profitability, black walnut syrup demand (price points) strongly surpasses maple syrup, although supply amounts are significantly lower. The average price per gallon of maple syrup in the United States was USD $37.50 in 2022 (Shahbandeh 2024), while in earlier reports, black walnut syrup prices were significantly higher, from $150 to $250 per gallon, with retail prices reaching over $500 per gallon in regions such as West Virginia (Rechlin 2022).

While maple syrup is well-researched and widely produced, there are many gaps in the foundational knowledge to support the expansion and adoption of black walnut syrup as a commodity. Assessing both consumer acceptability and flavor perceptions of black walnut syrup is essential for fostering market development. Consumer acceptability research ensures that novel products have a competitive edge, increasing the potential for broader market adoption and commercialization (Siegrist and Hartmann 2020). Additionally, exploring consumer attitudes provides valuable insights for targeting niche markets, such as gourmet food enthusiasts or consumers seeking locally sourced products (Aprile et al. 2016; Balderas-Cejudo et al. 2019). Characterizing key flavor attributes plays a significant role in guiding product development, allowing producers to adjust to meet consumer preferences (Appleton et al. 2021). Sensory knowledge informs marketing strategies by highlighting the most appealing aspects of a novel product (Abdolmohamad Sagha et al. 2022; Krishna and Schwarz 2013). Research on the flavor profiles, such as nuttiness or bitterness, of black walnut syrup (Matta et al. 2006) could also help differentiate it from maple syrup, offering a unique sensory experience that can be leveraged in marketing strategies.

Therefore, with the aim of providing a comprehensive understanding of the potential market adoption of black walnut syrup, the objectives of this study were to assess the consumer acceptability of black walnut syrup in comparison with maple syrup and characterize consumer descriptions of the unique flavor attributes of black walnut syrup. We hypothesized that consumer acceptability of black walnut syrup is similar to that of maple syrup and that syrup flavor attributes influence consumer acceptability.

Table 1. Sugar Concentration, Color Transmittance, and USDA Grade of Syrup Samples.

Syrup	Sugar Concn (°Brix)	Transmittance at 560 nm (%)	USDA syrup grade[i]
Maple2	67	54.66	Amber
PBW_commercial	68	3.09	Very Dark
PBW_UMN1	67	36.19	Dark
PBW_UMN2	66	64.62	Amber
BW_infused	66	40.91	Dark

[i]USDA syrup grade according to the USDA Maple Syrup Grading System guidelines (US Department of Agriculture–Agricultural Marketing Service 2015).

BW_infused = black walnut–infused syrup, Maple2 = pure maple syrup (control), PBW_commercial = pure black walnut syrup commercial, PBW_UMN1 = pure black walnut syrup produced using sap of black walnut trees from the University of Minnesota horticultural research center and cooked using propane, PBW_UMN2 = pure black walnut syrup produced using sap of black walnut trees from the University of Minnesota horticultural research center and cooked using a wood stove, USDA = US Department of Agriculture.

Material and Methods

Syrup samples. Five syrups were selected for this study. Syrups 1 and 2 (Maple1 and Maple2) comprised the same grade A pure maple syrup (Bethel, VT, USA). Syrup 3 (PBW_commercial) was a pure black walnut syrup purchased online (Cross Plains, WI, USA). Syrups 4 (PBW_UMN1) and 5 (PBW_UMN2) were pure syrups locally produced from sap collected from the black walnut grove at the University of Minnesota Horticultural Research Center, Excelsior, MN, USA (lat. 44.8683°N, long. 93.6361°W); PBW_UMN1 was cooked using propane, while PBW_UMN2 was cooked using a wood stove. The final sample, BW_infused (BW_infused), was a black walnut–infused syrup, described by the manufacturer as a blend of corn syrup and 25% maple syrup, with black walnut pieces ~0.5 cm in size infused into the product (Stockton, MO, USA).

The syrup samples used in this study were characterized based on their soluble solids content (°Brix) and color (Table 1). Before analysis, all syrup samples were brought to room temperature (~22 °C). Four technical replicates were prepared for each sample. Each measurement was performed in triplicate, and the mean values were used for final characterization. Soluble solids content (°Brix) was measured using a maple syrup digital refractometer (model BKS555; MISCO Refractometer, Cleveland, OH, USA). Color determination was performed according to the US Department of Agriculture maple syrup grading system guidelines (US Department of Agriculture–Agricultural Marketing Service 2015). A volume of 200 µL from each replicate was transferred into a clear, flat-bottom 96-well microplate. Transmittance at 560 nm was measured using a SpectraMax 190 microplate reader (Molecular Devices, San Jose, CA, USA) in percent transmittance (%T) mode, with distilled water used to calibrate 100% transmittance.

Participants. Potential black walnut syrup consumers were recruited through e-mail and word of mouth. Participants were required to be at least 18 years old, have purchased tree syrup within the past year, and have no known food allergies or sensitivities. A total of 151 individuals were initially recruited, with 106 attending the study sessions. Participants were scheduled for one of twelve sessions, with each session accommodating up to 25 participants. The recruiting and sensory evaluation procedures were reviewed and approved by the University of Minnesota Institutional Review Board, which granted the study exempt status.

Participant demographics. Participants ranged in age from 31 to 40 years up to 61 to 70 years, with a majority identifying as female, followed by males, and a small number identifying as nonbinary. Most participants reported higher household incomes (greater than $100,000 per year). In terms of purchasing behavior, participants indicated a preference for buying pure syrups more frequently than table syrups. Among commercially available processed syrups, Log Cabin® and Mrs. Butterworth® were the most commonly reported brands.

Taste panel design. Sensory analysis sessions were held at University of Minnesota Horticulture Research Center. Before the evaluation session began, participants were informed about the procedures, confidentiality, and the voluntary nature of the study and were provided contact information for any questions. Researchers gave a verbal introduction covering the taste panel setup, directions on how to taste the syrups, palate-cleansing procedures, the use of color samples, and a review of the instructions and scorecards.

Each participant received a tray containing six syrup samples (5 to 10 mL each) in labeled, transparent plastic cups with lids. The samples were labeled with three-digit randomized codes and served at room temperature. The grade A pure maple syrup (Maple1 and Maple2) was evaluated in duplicate: once as Maple1, the first sample evaluated by all participants in all sessions, and again as Maple2 in balanced orders among the other syrup samples. A William's Latin square design was used to balance the taste position of syrups and carryover effects. In addition to the samples, participants received an instruction sheet, a sociodemographic survey sheet, six evaluation scorecards, and a color reference kit consisting of four cups of commercial maple syrup labeled as Golden, Amber, Dark, and Very Dark (Fig. 1). Kellogg's Eggo® frozen pancakes were used as carriers for the syrup samples, following the method described by Matta et al. (2006). Panelists were served warm pancakes cut into six pieces. Panelists were instructed to use one piece for each syrup sample evaluated. Each participant's station also included a 500 mL bottle of drinking water, a fork, a napkin, and a plate.

Consumers were asked to rate each syrup based on the following attributes: color, appearance liking, flavor liking, overall syrup liking, and flavor intensity for several specific flavor attributes. The flavor attributes were selected from the lexicon developed for black walnut syrup by Matta et al. (2006), which included caramelized/butterscotch, nutty, woody, maple, burnt, and bitter. Color perception was assessed by comparing each syrup to the four samples from the color reference kit and indicating the number of the display sample that most closely matched the sample color. Overall liking and flavor liking were rated using the labeled affective magnitude scale (Cardello and Schutz 2004), while the intensity of the flavor attributes was measured using the general labeled magnitude scale of Green et al. (1993). The sociodemographic information and syrup purchasing habits of the evaluators were also collected.

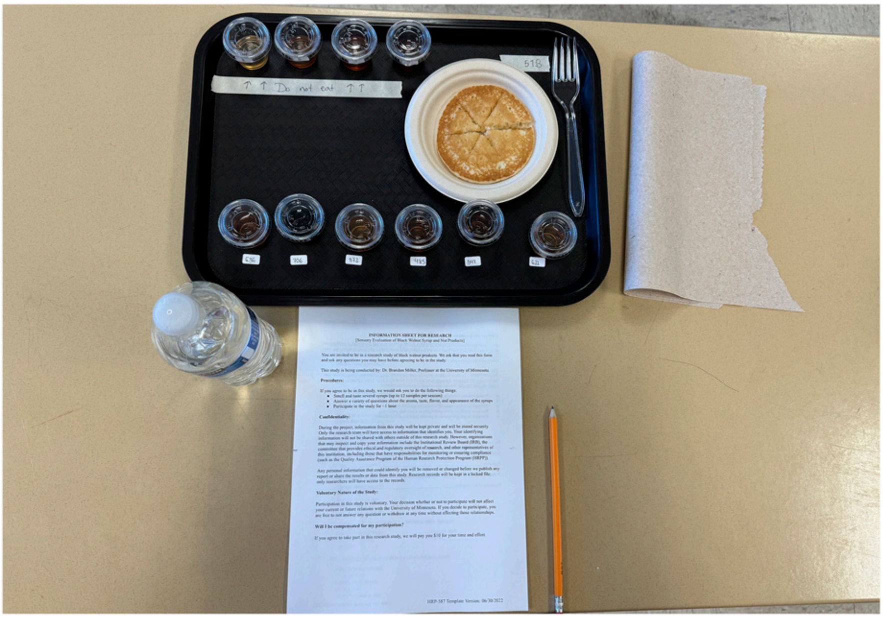

Fig. 1. Sample setup for the black walnut syrup taste panel, showing coded syrup samples arranged at the bottom of the tray for blind evaluation, with color reference samples on the top left. The setup includes a warmed pancake cut into six pieces, a bottle of water, a pencil, a napkin, and the evaluation forms for recording the assessments of the participants.

Sensory characteristics marked on the linear scales were transformed into quantitative data points based on measuring (mm) from the beginning (far left-hand side) of the scale to wherever the panelist made their mark (Anderson et al. 2020; Kostick et al. 2017; Yue et al. 2020). This value was then divided by the total length of the scale and then multiplied by 10 for data points on a 10-point scale.

Statistical analysis. The ratings for the first sample evaluated by all participants (Maple1) were excluded from the analysis to mitigate first-sample order bias (Lee and Meullenet 2010), because this sample was not balanced by tasting position. For the qualitative attribute color, a χ^2 goodness-of-fit test was conducted for each syrup to assess whether the frequency of each assigned color grade (1 to 4) differed significantly from an equal distribution, with expected counts based on a 1:1:1:1 ratio assumption. For the quantitative attributes—overall liking, appearance liking, flavor liking, caramel, nutty, maple, woody, burnt, and bitter—a one-way analysis of variance (ANOVA) was conducted to determine whether there were statistically significant differences in consumer responses among the black walnut syrups and the maple syrup, using the following model:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + \gamma_k + \epsilon_{ijk} \quad [1]$$

where Y_{ijk} is the response for the kth participant rating the ith syrup sample in the jth taste position; μ is the overall mean of the response; α_i represents the fixed effect of the ith syrup sample, β_j represents the fixed effect of the jth taste position; γ_k represents the random effect of the kth participant; and ϵ_{ijk} is the residual error term, assumed to be normally distributed with mean zero and constant variance σ^2. To further explore these differences, Tukey's test assessed pairwise comparisons among all syrup samples. Principal component analysis (PCA) was conducted on the mean ratings for each syrup samples averaged across all participants (resulting in a 5 × 9 data array) to identify patterns and reduce the dimensionality of the sensory and flavor data, helping to visualize the relationships between syrup attributes and consumer liking. Additionally, multiple linear regression analysis was performed to explore the relationship between key sensory attributes and overall liking, and flavor liking, providing insights into the flavors that most influenced consumer perception and preference. The final models, shown below, included these attributes based on their hypothesized influence on consumer preference:

$$\text{Overall liking} = \beta_0 + \beta_{1(\text{Caramel})} + \beta_{2(\text{Nutty})} + \beta_{3(\text{Woody})} + \beta_{4(\text{Maple})} + \beta_{5(\text{Burnt})} + \beta_{6(\text{Bitter})} + \epsilon \quad [2]$$

$$\text{Flavor liking} = \beta_0 + \beta_{1(\text{Caramel})} + \beta_{2(\text{Nutty})} + \beta_{3(\text{Woody})} + \beta_{4(\text{Maple})} + \beta_{5(\text{Burnt})} + \beta_{6(\text{Bitter})} + \epsilon \quad [3]$$

where β_0 is the intercept, which is the baseline level of overall liking (Eq. [2]) or flavor liking (Eq. [3]) when all sensory attribute values are zero. $\beta_{1\ (\text{Caramel})}$ is the coefficient for the caramel attribute, representing the effect of caramel flavor on overall liking and flavor; $\beta_{2\ (\text{caramel})}$ is the coefficient for the nutty attribute, indicating how the presence of a nutty flavor influences overall liking and flavor; $\beta_{3(\text{Woody})}$ is the coefficient for the woody attribute, showing the effect of woody notes on overall liking and flavor; $\beta_{4(\text{Maple})}$ is the coefficient for the maple attribute, capturing the influence of a maple flavor on overall liking and flavor; $\beta_{5(\text{Burnt})}$ is the coefficient for the burnt attribute, reflecting the impact of burnt notes on overall liking and flavor; $\beta_{6(\text{Bitter})}$ is the coefficient for the bitter attribute, representing the effect of bitterness on overall liking and flavor; and ϵ is the error term, accounting for the variation in overall liking and flavor not explained by the sensory attributes in the model. All statistical analyses were conducted using R (version 4.3.3; R Core Team).

Results

Overall, the commercial black walnut syrup (PBW_commercial) and the black walnut syrup cooked using a wood stove (PBW_UMN2) were perceived as the darkest syrups, while the black walnut syrup cooked using propane (PBW_UMN1) and the black walnut–infused syrup (BW_infused) were the lightest (Fig. 2). The maple syrup (Maple2) was consistently perceived between the darkest and lightest syrups (Fig. 2). The χ^2 test results indicate that color grades were not equally distributed for each syrup, suggesting that participants consistently assigned certain colors more frequently to each syrup ($P < 0.001$).

The syrups evaluated differed for all attributes (Table 2). In terms of comparison with Maple2, the PBW_UMN1 and PBW_UMN2 syrups were similar for appearance liking, flavor liking, caramel, nutty, and maple. BW_infused was also similar to Maple2 for nutty, woody, burnt, and bitter. In contrast, PBW_commercial differed markedly from Maple2 for all evaluated attributes, with lower ratings in overall liking, appearance, flavor liking, and caramel attributes but significantly higher scores in nutty, woody, burnt, and bitter characteristics (Table 2).

Flavor liking and overall liking were negatively correlated with bitter and burnt flavors. These liking attributes, along with maple and caramel flavors, were positively associated with each other and aligned along a common consumer preference axis (Fig. 3). Nutty and woody were strongly and positively correlated with each other and with principal component (PC) 1, while bitter had a moderate negative correlation with PC1. Liking attributes (overall, flavor, and appearance) were positively related to component 2, as were maple and caramel flavors, while bitter and burnt were negatively related to component 2. The first two principal components, accounted for 76.7% and 17.5% of the total variance, respectively, explaining 94.2% of the variation in the data.

The attributes caramel and maple were significant positive predictors of overall liking. For each unit increase in the caramel score, overall liking increased by 0.17 units, and for each unit increase in the maple score, overall liking increased by 0.11 units. Conversely, there was a significant negative relationship between the bitter attribute and overall liking, with overall liking decreasing by 0.16 units for each unit increase in the bitter score. The woody, nutty, and burnt attributes were not significant predictors of overall liking.

For flavor liking, the attributes caramel, nutty, and maple were significant positive

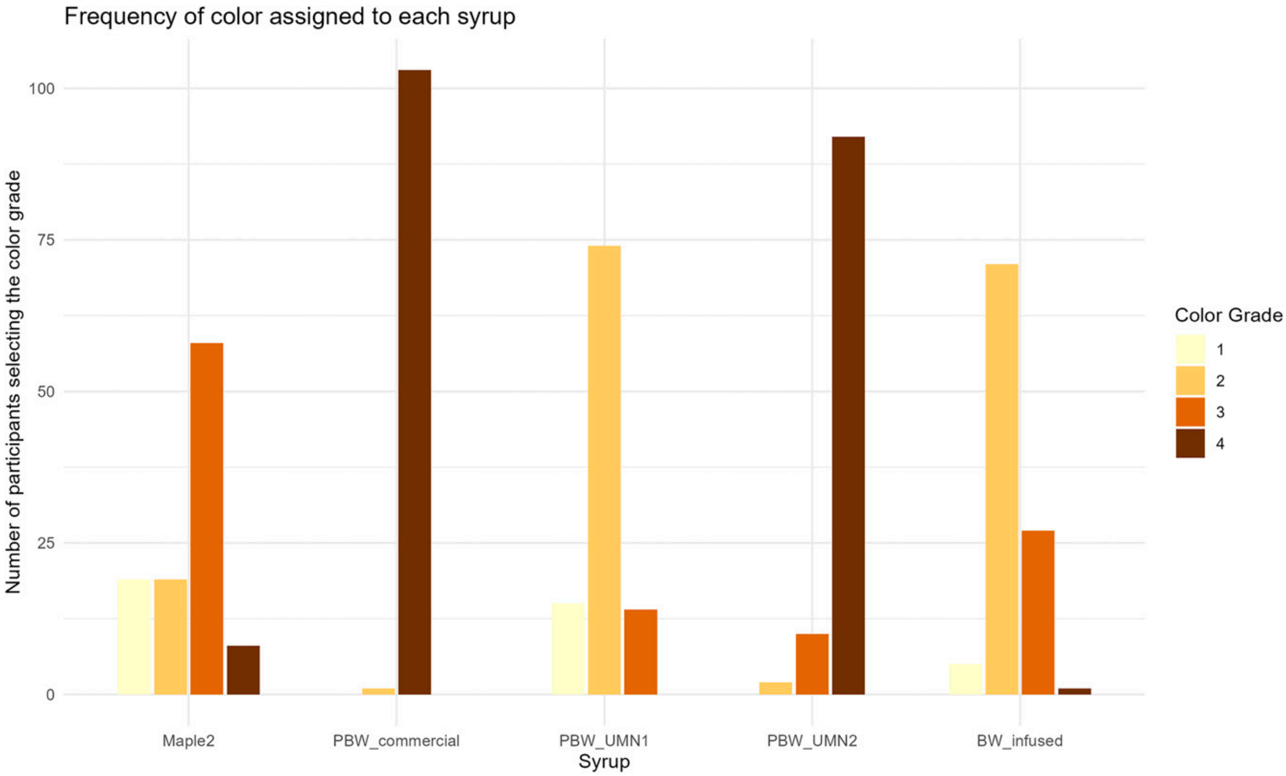

Fig. 2. Bar plot illustrating the number of times each syrup was attributed a specific color, ranging from 1 (lightest) to 4 (darkest). BW_infused = black walnut–infused syrup, Maple2 = pure maple syrup (control), PBW_commercial = pure black walnut syrup commercial, PBW_UMN1 = pure black walnut syrup produced using sap of black walnut trees from the University of Minnesota horticultural research center and cooked using propane, PBW_UMN2 = pure black walnut syrup produced using sap of black walnut trees from the University of Minnesota horticultural research center and cooked using a wood stove.

predictors. Specifically, flavor liking increased by 0.15 units for each unit increase in the caramel score, by 0.21 units for each unit increase in the nutty score, and by 0.33 units for each unit increase in the maple score. There was a highly significant negative relationship between the bitter attribute and flavor liking, with a decrease of 0.58 units in flavor liking for each unit increase in the bitter score. The burnt and woody attributes were not significant predictors of flavor liking.

Discussion

Description of participants. The age distribution of the participants could suggest that the results of the taste panel reflect preferences that might be more common among older consumers, who tend to have more established taste preferences and might favor traditional or familiar flavors such as pure maple syrup. The income distribution indicated that most respondents were from middle to upper income, which could further bias the results toward consumers who can afford premium products like pure syrups. These higher-income participants might place more value on artisanal or natural products, aligning with the observed preference for pure maple syrup over processed syrup. The demographic profile of the participant group likely shaped their evaluations of the syrups in the taste panel, and their preferences might not fully represent a broader, more diverse population. Therefore, while these findings offer preliminary insights into the preferences of consumers who may be more inclined to purchase premium products such as black walnut syrup, they should be interpreted cautiously. Broader consumer groups, including younger, lower-income, or more diverse individuals, may have different taste preferences or purchasing behaviors.

Syrup color and syrup flavor. The variation in color observed among the syrups in this study corresponded to specific differences in flavor intensity and sensory profiles. PBW_commercial and PBW_UMN2, perceived as darker syrups, displayed higher woody, burnt, and bitter scores, with PBW_UMN2 also showing the highest caramel score, indicative of robust flavors (Table 2).

Table 2. Means (±standard error) for the evaluated sensorial attributes of different syrups.

Syrup	Overall liking	Appearance liking	Flavor liking	Caramel	Nutty	Maple	Woody	Burnt	Bitter
Maple2	7.5 (±0.2) ab[i]	7.2 (±0.2) a	7.3 (±0.2) a	3.2 (±0.2) a	1.4 (±0.1) b	2.8 (±0.2) a	1.6 (±0.2) bc	0.6 (±0.1) c	0.4 (±0.1) c
PBW_commercial	6.2 (±0.2) c	5.7 (±0.2) c	5.5 (±0.3) b	2 (±0.2) c	2.3 (±0.2) a	1.1 (±0.1) b	3.5 (±0.3) a	4.1 (±0.3) a	2 (±0.2) a
PBW_UMN1	6.7 (±0.2) c	6.9 (±0.2) ab	6.8 (±0.2) a	2.9 (±0.2) ab	1.5 (±0.1) b	2.3 (±0.2) a	1 (±0.1) c	0.6 (±0.1) c	0.4 (±0.1) c
PBW_UMN2	7.8 (±0.1) a	7.0 (±0.2) a	6.9 (±0.2) a	3.7 (±0.2) a	2 (±0.2) ab	2.3 (±0.2) a	2 (±0.2) b	1.5 (±0.2) b	0.9 (±0.1) b
BW_infused	6.9 (±0.2) bc	6.1 (±0.2) bc	5.9 (±0.2) b	2.2 (±0.2) bc	1.8 (±0.2) ab	1.4 (±0.1) b	1.4 (±0.2) bc	0.6 (±0.2) c	0.8 (±0.1) bc
F value[ii]	13.71	15.69	17.49	17.52	7.3	22.62	36.94	118.35	37.43
P value[iii]	$P < 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.001$

[i] Means followed by the same letter within a column do not differ according to Tukey's honestly significant difference test ($P < 0.05$).
[ii] *F* values are from ANOVA.
[iii] *P* values are from ANOVA.
ANOVA = analysis of variance, BW_infused= black walnut–infused syrup, Maple2 = pure maple syrup (control), PBW_commercial = pure black walnut syrup commercial, PBW_UMN1 = pure black walnut syrup produced using sap of black walnut trees from the University of Minnesota horticultural research center and cooked using propane, PBW_UMN2 = pure black walnut syrup produced using sap of black walnut trees from the University of Minnesota horticultural research center and cooked using a wood stove.

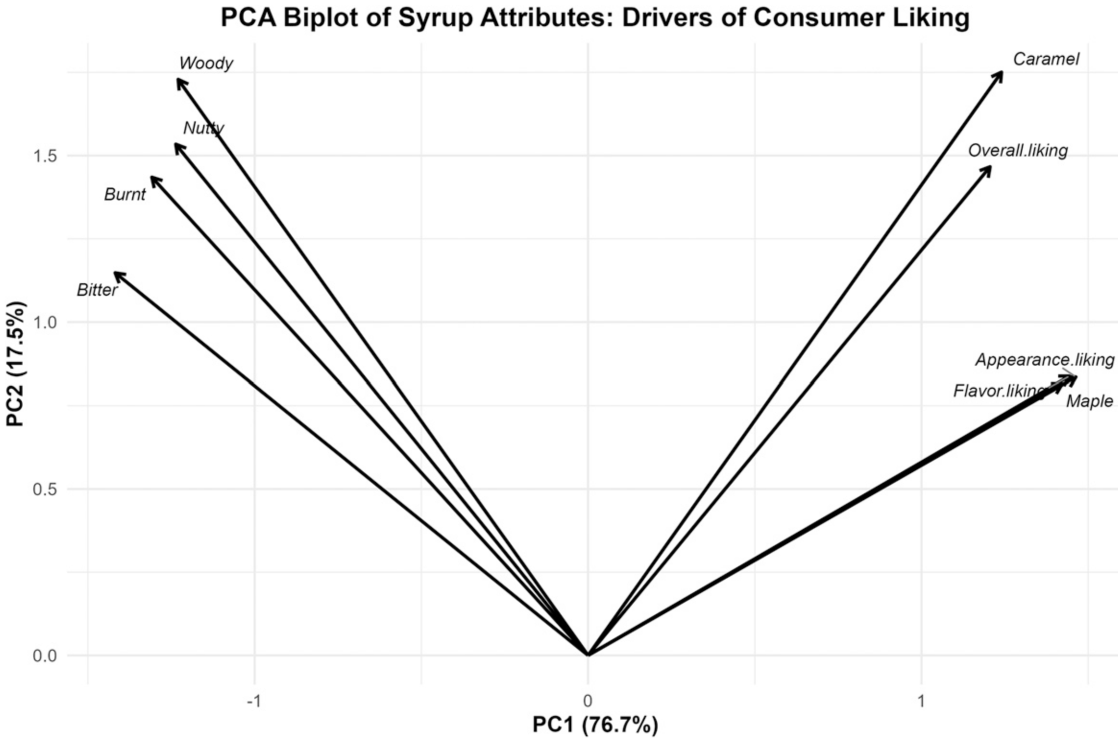

Fig. 3. Principal component analysis (PCA) biplot of black walnut syrup attributes for the first two components [principal components 1 (PC1) and 2 (PC2)]. Vectors (arrows) represent the sensory attributes. The direction and length of each vector indicate how each attribute contributes to the principal components, with attributes pointing in the same direction being positively correlated and those pointing in opposite directions being negatively correlated.

Conversely, PBW_UMN1 and BW_infused, perceived as lighter syrups, exhibited lower scores for woody, burnt, and bitter notes, suggesting a milder flavor profile (Table 2). The link between syrup color and flavor is well documented, particularly in maple syrup, in which darker syrups tend to exhibit stronger, more robust flavors, and lighter syrups offer milder, more delicate flavors (Belford et al. 1991; Singh et al. 2014). This relationship is driven by chemical reactions involving reducing sugars like fructose and glucose, along with amino acids, contributing not only to the syrup's flavor but also to its color intensity (Perkins and Van den Berg 2009). Another factor associated with changes in color and flavor is microbial activity, which increases during the sugaring season. Microorganisms metabolize sap compounds, producing by-products such as organic acids and phenolic compounds, which result in darker syrups with more complex flavor profiles (N'guyen et al. 2018).

Syrup sensory attributes and consumer acceptability. The differences among syrups for all attributes revealed by the ANOVA is expected given the diverse sources of the syrups and the unique processing methods employed by each producer. The composition and flavor profile of syrup might be influenced by numerous factors, including tree genetics, environmental conditions during sap collection, sap storage practices before boiling, boiling temperature, the energy source used during the boiling process, and cooking time, among others (Garcia et al. 2020; Mohammed et al. 2023; N'guyen et al. 2018). These variables contributed to the wide variability in syrup characteristics, leading to distinct sensory experiences across samples.

PBW_UMN2 was the most liked syrup in this study (Table 2), demonstrating strong potential for broad consumer appeal. Its high scores for attributes such as caramel and maple, combined with its distinctive black walnut flavors like nuttiness and woodiness, even surpassing those of Maple2, underscore its balance of familiar and unique sensory characteristics. This balance created a robust yet approachable flavor profile, likely contributing to its wide acceptability among participants. Similarly, PBW_UMN1 showed notable similarity to Maple2 in flavor liking, with comparable scores for attributes such as maple, nuttiness, burnt, and bitterness, indicating its potential to be well received as a pure syrup option. However, its slightly lower overall liking compared with PBW_UMN2 (Table 2) suggests that refinements in balancing these sensory elements could further enhance its acceptability. In contrast, PBW_commercial was the least liked syrup (Table 2), with high bitterness and burnt flavors, coupled with reduced caramel and maple notes likely contributing to its lower consumer appeal.

Our findings reaffirm that attributes, such as caramel and maple, are strongly associated with higher overall liking (Table 3). Sweetness, often linked to positive emotions and food acceptability (Mennella et al. 2016; Mora and Dando 2021), plays a critical role in driving consumer preferences for syrups. Caramelized notes, a product of Maillard reactions, are particularly valued across various

Table 3. Multiple linear regression analysis for overall liking and flavor liking.

Liking	Term	Estimate[i]	Standard error	*t* value	*P* value
Overall	(Intercept)	6.49	0.14	45.88	<0.001
	Caramel	0.17	0.04	4.31	<0.001
	Nutty	0.04	0.05	0.71	0.479
	Woody	0.06	0.05	1.20	0.230
	Maple	0.11	0.05	2.34	0.019
	Burnt	−0.08	0.06	−1.48	0.139
	Bitter	−0.16	0.07	−2.22	0.026
Flavor	(Intercept)	5.59	0.13	44.31	<0.001
	Caramel	0.15	0.03	4.40	<0.001
	Nutty	0.21	0.04	4.66	<0.001
	Woody	0.09	0.04	1.94	0.052
	Maple	0.33	0.04	8.14	<0.001
	Burnt	−0.09	0.05	−1.71	0.087
	Bitter	−0.58	0.07	−8.73	<0.001

[i] Estimate represents the size of the change in liking associated with a 1-point increase in the intensity rating of a specific attribute.

food products for their ability to enhance sensory appeal (Paravisini et al. 2017; Starowicz and Zieliński 2019). In this study, syrups with a sweeter, caramel-like profile, akin to maple syrup, such as PBW_UMN1 and PBW_UMN2 achieved higher liking scores, highlighting the role of familiarity in shaping consumer preferences.

Conversely, high bitterness and burnt flavors significantly detracted from consumer liking, as observed in syrups like PBW_commercial and BW_infused (Table 2). A significant negative relationship between bitterness and flavor liking (Table 3) aligns with broader findings on consumer preferences (Pagliarini et al. 2021). Bitterness and burnt flavors often evoke negative emotions, as seen in other products like coffee and chocolate, in which excessive bitterness reduces liking and purchase intent unless counterbalanced by other elements (Pedersen et al. 2023; Pinsuwan et al. 2022).

While woody and nutty flavors are distinctive characteristics of black walnut syrup, their lack of significance in predicting overall liking (Table 3) suggests they may resonate more with niche consumers rather than the broader market. However, nuttiness, in particular, positively contributed to the flavor experience (Table 3) and might serve as a defining characteristic and potential selling point for black walnut syrup. In fact, PBW_UMN2 showed higher nuttiness than maple, and PCA revealed that the nutty attribute was positively correlated to overall liking and flavor liking (Fig. 3).

The complex flavor profile of black walnut syrup—often described as nutty, woody, and earthy (Matta et al. 2006)—can pose challenges in achieving broad consumer appeal. These intense, less familiar flavors might lower acceptance when directly compared with the smoother, sweeter profile of maple syrup (Perkins and Van den Berg 2009; Saraiva et al. 2022). However, these distinctive qualities of black walnut syrup, when carefully balanced with caramel flavor, as in PBW_UMN2, can enhance its value proposition as a specialty product.

Conclusions. The findings from this study offer valuable insights into the market potential of black walnut syrup. PBW_UMN2 emerged as well liked as the maple syrup, showcasing strong consumer acceptability through its balanced combination of familiar flavors, such as caramel and maple, and distinctive black walnut characteristics, including nuttiness and woodiness. PBW_UMN1 demonstrated a flavor profile comparable to maple syrup, further supporting the acceptability of black walnut syrups among consumers. However, strong flavors such as burnt and bitter, present in some black walnut syrups, were found to detract from consumer acceptability. Therefore, developing a product that balances familiar flavors like caramel with moderate woodiness and nuttiness while avoiding burnt and bitter notes is key to establishing black walnut syrup as a distinct and appealing specialty product. These findings support the potential of black walnut syrup to fill a unique niche in the specialty syrup market, offering new opportunities for growers and producers seeking to diversify their product offerings and add value to black walnut trees.

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