

Using different types of wheat flour produce more palatable whole wheat breads

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Abstract

Despite the recommendations listed in the Dietary Guidelines for Americans, the average consumption of whole grains in the United States is vastly insufficient. Inadequate consumption of whole grains in favor of refined grains is associated with an increased risk of developing a wide variety of diseases including cancer, diabetes, and cardiovascular disease. Breads serve as a staple grain source across American households, but a primary barrier to the consumption of whole wheat breads is their increased bitterness in comparison to breads made from refined wheat. The objective of this study was to assess if consumer liking scores differed across breads made using 11 different whole wheat flours, and if the most liked sample also produced the highest proportion of just-about-right (JAR) intensity ratings. When liking scores were compared via a two-way ANOVA and an LSD post-hoc test ($\alpha = 0.05$), it was found that every bread type differed significantly from at least three of the other varieties. Descriptive statistics revealed the Vida flour type produced the most liked bread with an average liking score of 5.595 ± 0.134 (out of a total possible rating of 9), and the JAR intensity data agreed with this: the Vida sample had the highest percent of JAR ratings at 77.3% when averaged across aroma, flavor, color, and texture. Regression analyses furthered this, showing that percent JAR ratings for aroma, flavor and texture were positively correlated with increased sample liking (R^2 of 0.3438, 0.7928, and 0.4857 respectively), but less so for color (R^2 of 0.1423). The results presented in the study may assist product development efforts towards more palatable whole wheat breads, which in turn may encourage more widespread consumption amongst American consumers.

Introduction

The current Dietary Guidelines for Americans recommend that individuals consume 45 to 65 percent of their daily caloric intake from carbohydrate sources, with an emphasis on fiber-rich

vegetables, fruits, and whole grains and cereals (HHS and USDA 2020). Consumption of whole grain foods has been repeatedly demonstrated to be associated with decreased risk for development of diseases such as cancer and type II diabetes (Montonen et al. 2003, Vecchia et al. 2003, Zhang et al. 2020). However, while the average consumption of whole grain foods has increased over the past 20 years, Americans are still vastly under consuming whole grain foods in favor of refined grains (Ahluwalia et al. 2019). Although dietary patterns as a whole are complex and multifactorial, the sensory properties of foods and their subsequent effect on liking has widely been shown to play a key role in food choice (Clark 1998, Boesveldt 2017). Breads are a staple source of grains in many American households, but whole wheat breads tend to be more bitter than their refined counterparts. This is attributed to compounds produced by the Maillard reaction, fermentation, and enzymatic activity during the production of whole wheat bread (Jiang and Peterson 2013, Bin and Peterson 2016). It has been suggested that bitterness is a major hinderance to the consumer acceptance of whole wheat bread (Bakke and Vickers 2007, McMackin et al. 2013).

The sensory characteristics of breads vary depending on processing factors such as level of grain refinement and preparation methods. However, the type of wheat used in flour production also plays a large role in the finished bread's properties (Chang and Chambers 1992). Using different types of wheat in whole wheat breads can serve to positively influence texture, flavor, and appearance without nutritional drawbacks like the loss of fiber and micronutrients associated with refining (Gomez et al. 2020).

The objective of this study was to assess if using different types of whole wheat flour in breads produced different liking scores among consumer panelists, and if so, which flour type produced the most favorable scores. It was hypothesized that the breads made with each flour variant would

produce different panelist liking scores, and that the most liked bread type would have the highest proportion of panelists rate its aroma, flavor, color, and texture characteristics as just-about-right (JAR.) A handful of other papers have evaluated consumer preferences between whole and refined wheat breads (Peryam 1960, Vickers et al. 1981), but few have examined differences in consumer liking across types of whole wheat breads made using different flours. The liking data collected in this study support the development of new whole wheat breads by providing insight into what types of flours consumers like most.

Materials and Methods

Bread Baking

11 different types of hard-bread wheat flours were milled by Ardent Mills (Denver, CO, USA.) The flour types were named as follows: Joe, Linkert, Advance, Ogden Snowcrest, Snowmass, SY Soren, Everest, Einkorn, Rogue De Bordeaux, Vida, and White Sonora. The fresh flour samples were stored for approximately one year at -40°C to minimize degradation reactions. 24 hours prior to panelist evaluation periods, five loaves of each of the tested bread types (either 3 or 4 varieties dependent on the week) were baked in 6-inch-by-3.5-inch non-stick loaf pans using a modified version of the AACC method 10-10B optimized straight-dough bread-making method (AACC 1999). The formula for the dough is displayed below in Table 1. The ingredients were mixed in a dough mixer for approximately 2.5 minutes until a spongy dough was formed. The dough was fermented for 52 min at 30°C and 85% relative humidity, then proofed in the loaf pans for 25 min and 33 min. Finally, the dough was baked at 215°C alongside a container filled with 1 L of water for 17 min.

Table 1. Bread dough formula based on optimized straight-dough AACCC method 10-10B.

Ingredients	Amount (g)
Flour, 14% moisture basis	500
Yeast (active dry)	26.5
Sucrose	30
Salt (NaCl)	7.5
Shortening	15
Total water	325-350 (65-70% flour weight)

Sample Preparation

One hour before each testing session, a deli slicer was used to cut the loaves into 1 cm thick slices. The bottom and top sections of crust on each slice were cut away, and the remaining portion was divided into four evenly sized pieces, as shown in Figure 1. Three bread squares were placed into each sample cup and labeled with an assigned 3-digit identification number. In week one, breads made from wheat flour samples Joe, Linkert, and Advance were tested; Ogden Snowcrest, Snowmass, SY Soren, and Everest were tested in week two; and Einkorn, Rogue De Bordeaux, Vida, and White Sonora were tested in week three. The flour types for each week were randomly selected.

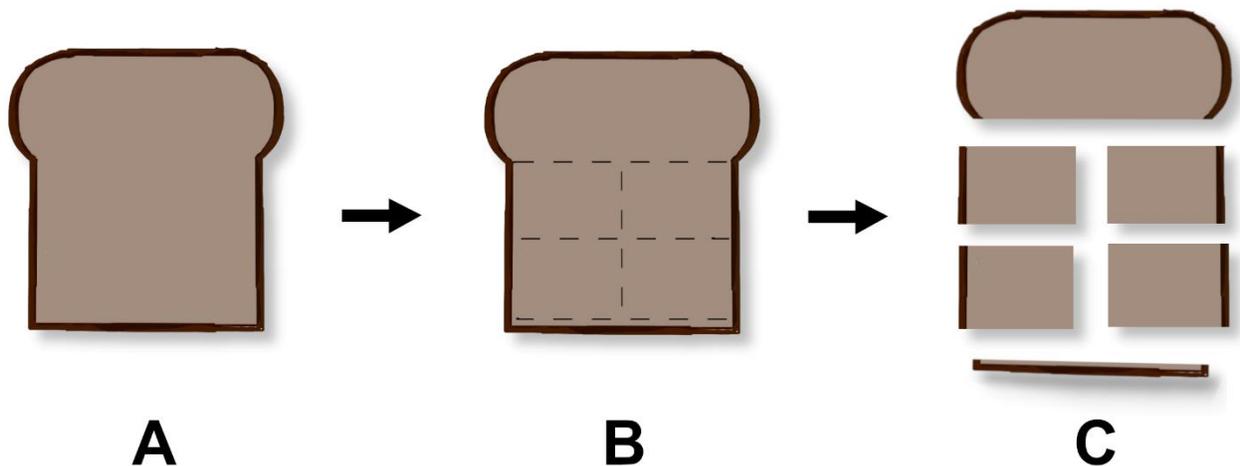


Figure 1. Diagram of bread sample preparation. (A) A deli slicer was used to slice the bread loaf into 1 cm thick slices (B) which were then cut with a bread knife following the pattern shown. (C) The top and bottom pieces were discarded, yielding four evenly sized pieces of bread.

Panelist Recruitment

133 panelists (73 female and 60 male, ages 19-73) were initially recruited from the sensory database of the Ohio State University, 91 of which completed the entire study. All subjects were self-reported regular consumers of whole wheat bread (three or more times per month.) The participants were all registered under written informed consent (2013B0585) and instructed to not eat, drink, or smoke within 30 minutes of their scheduled testing session.

Testing Sessions

The panelists arrived at the sensory evaluation center at the Ohio State University and their temperatures were taken prior to testing to screen for COVID-19 symptoms. Once cleared, they were isolated into individual testing booths with white lighting. A maximum of six panelists were tested in each one-hour interval. During the testing session, the panelists were provided with the bread samples one at a time in a randomized, counter-balanced order. Panelists were also given water and unsalted saltine crackers for palate cleansing between samples. They were asked to taste each sample and then answer a series of questions presented via the open-source software Psychopy on a computer screen; the data collected included their initial hunger rating on a 5-point scale, overall liking of bread samples on a 9-point hedonic scale, JAR ratings for aroma, flavor, color, and texture on a 5-point scale, and a variety of other metrics (Appendix A.) All panelists were recruited to participate over the three-week test series, allowing them to sample each of the 11 bread types.

Data Analysis

The overall liking data collected for each bread sample were compared via descriptive statistics and two-way ANOVA without replication ($\alpha = 0.05$.) Once it was established that significant differences existed across sample types, an LSD post-hoc test was done to discover where the

differences were present. The raw JAR scale data on aroma, flavor, color, and texture were plotted on histograms and interpreted visually, and the relationships between liking and the percent of JAR ratings in each category were assessed via regression analysis.

Results and Discussion

As shown below in Figure 2, panelist liking across the different types of whole wheat bread was generally consistent, with Vida being the most liked at an average liking of 5.595 ± 0.134 and Advance being the least at an average of 4.389 ± 0.170 . These numbers fall relatively medially on the 9-point hedonic scale, as a score of one indicates “least liked” and a score of nine indicates “most liked.”

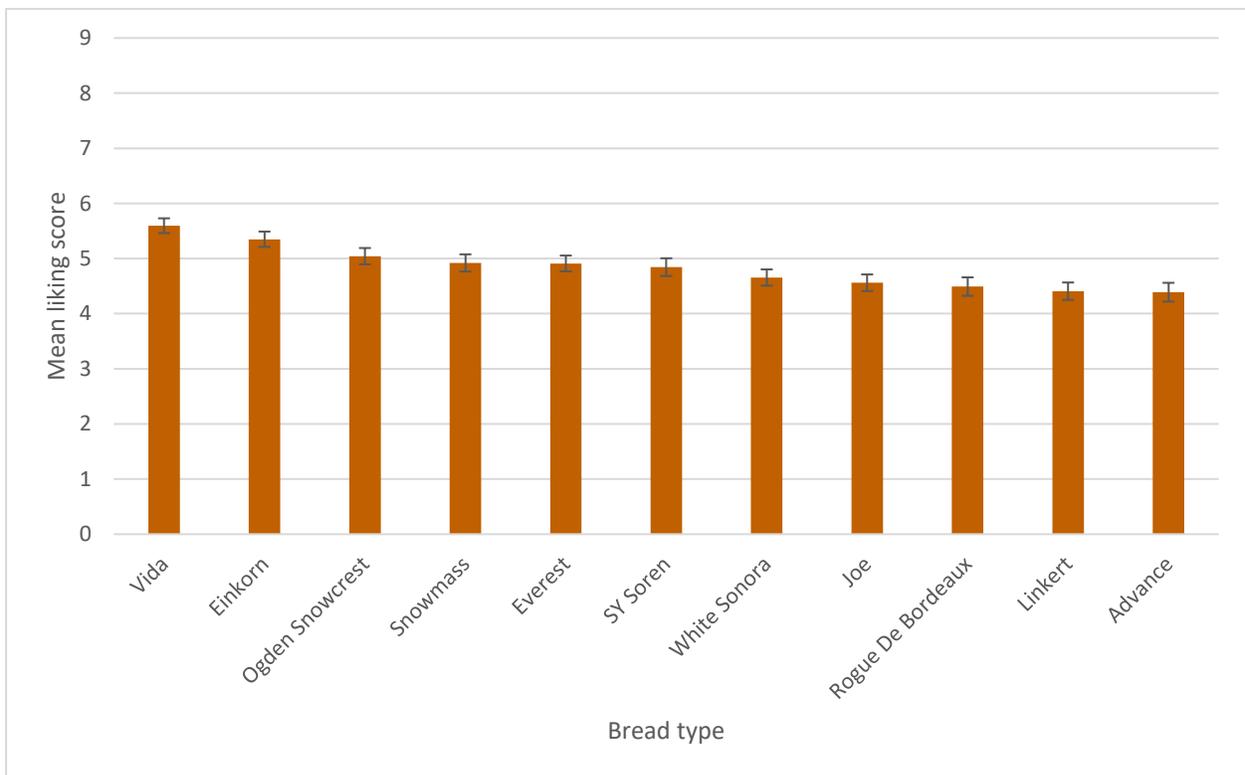


Figure 2. Average liking scores for different bread types measured on a 9-point hedonic scale (n=123). Error bars represent the standard error of the mean (SEM).

Although the descriptive statistics show that liking scores are fairly similar across bread samples, further analysis via a two-way ANOVA and an LSD post-hoc test ($\alpha = 0.05$) showed statistically significant differences across many of the bread types (Table 2.)

Table 2. Comparisons between average overall liking scores of 11 different whole wheat bread types (n=123). *indicates significant difference between compared types according to two-way ANOVA and LSD post-hoc test ($\alpha = 0.05$).

Flour Type	Joe	Linkert	Advance	Ogden Snowcrest	Snowmass	SY Soren	Everest	Einkorn	Rogue De Bordeaux	Vida	White Sonora
Joe		0.404	0.350	0.009*	0.049*	0.122	0.056	<0.001*	0.707	<0.001*	0.602
Linkert	0.404		0.919	0.001*	0.005*	0.017*	0.006*	<0.001*	0.647	<0.001*	0.176
Advance	0.350	0.919		<0.001*	0.004*	0.013*	0.004*	<0.001*	0.576	<0.001*	0.145
Ogden Snowcrest	0.009*	0.001*	<0.001*		0.506	0.277	0.473	0.093	0.003*	0.003*	0.035*
Snowmass	0.049*	0.005*	0.004*	0.506		0.672	0.958	0.019*	0.019*	<0.001*	0.148
SY Soren	0.122	0.017*	0.013*	0.277	0.672		0.711	0.006*	0.055	<0.001*	0.306
Everest	0.056	0.006*	0.004*	0.473	0.958	0.711		0.017*	0.022*	<0.001*	0.163
Einkorn	<0.001*	<0.001*	<0.001*	0.093	0.019*	0.006*	0.017*		<0.001*	0.180	<0.001*
Rogue De Bordeaux	0.707	0.647	0.576	0.003*	0.019*	0.055	0.022*	<0.001*		<0.001*	0.370
Vida	<0.001*	<0.001*	<0.001*	0.003*	<0.001*	<0.001*	<0.001*	0.180	<0.001*		<0.001*
White Sonora	0.602	0.176	0.145	0.035*	0.148	0.306	0.163	<0.001*	0.370	<0.001*	

These data confirm the primary hypothesis that the breads made from the different types of whole wheat flours would produce different average liking scores. All of the bread samples were significantly different from at least three of the other samples, with many of breads being different from six other varieties. Vida was significantly different from every other tested sample except for Einkorn, which agrees with Figure 2 as Einkorn was the second most liked bread type in the group. Visual inspection of the JAR data for all samples (Appendix B) plotted on histograms confirms the secondary component of the hypothesis, which predicted the most liked bread would produce the highest proportion of optimal ratings for its aroma, flavor, color, and texture characteristics. As shown in Figure 3a-d, the percents of panelists who rated Vida's aroma, flavor, color, and texture as just-about-right were 65.9, 64.8, 89.4, and 89.3% respectively. Vida had the highest percent of panelists give it a JAR rating when averaged across all attributes at 77.3%.

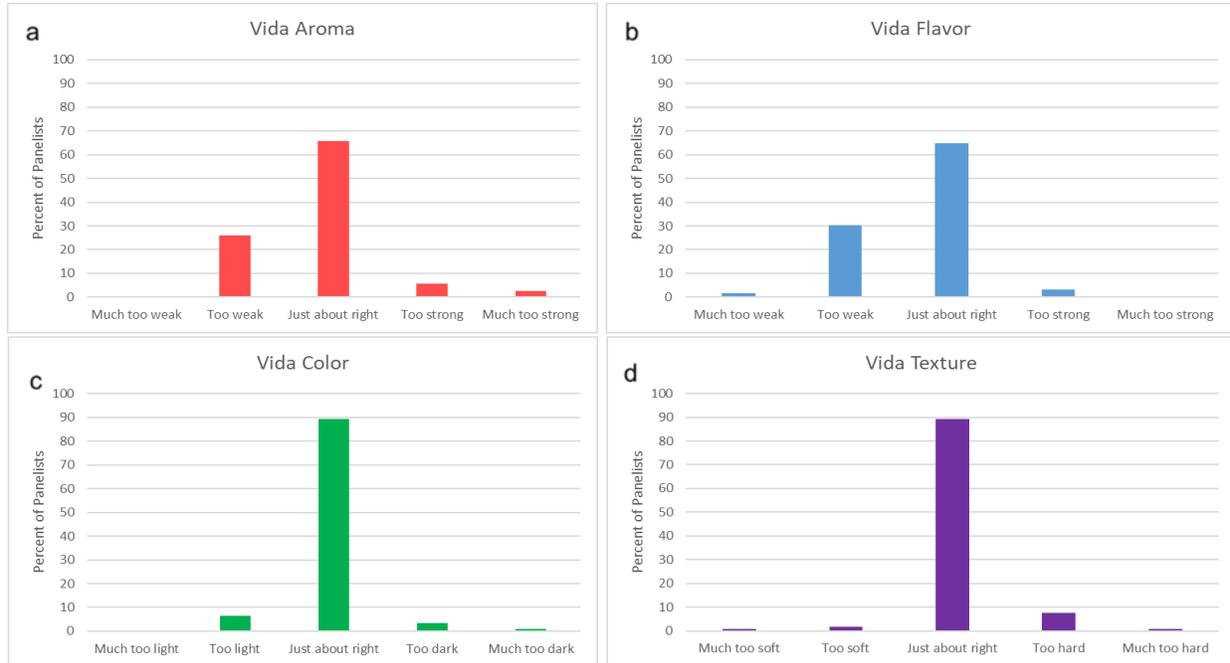


Figure 3a-d. Distributions of just-about-right (JAR) ratings for a.) Aroma (n=123) b.) Flavor (n=122) c.) Color (n=123) and d.) Texture (n=121) attributes of whole wheat bread made using Vida flour.

The secondary hypothesis is furthered by the regression analyses of the mean liking scores and the percent JAR ratings for all categories (Figure 4a-d). A positive correlation was observed between liking and percent JAR ratings, regardless of the category (but the strength of the relationship varied based on the attribute of interest.) Flavor and liking produced the highest R^2 of 0.7928 while color and liking produced the lowest of 0.1423. These data indicate that while optimal levels of flavor, aroma, and texture tended to be positively related to liking, the color of the samples seemed to play less of a role.

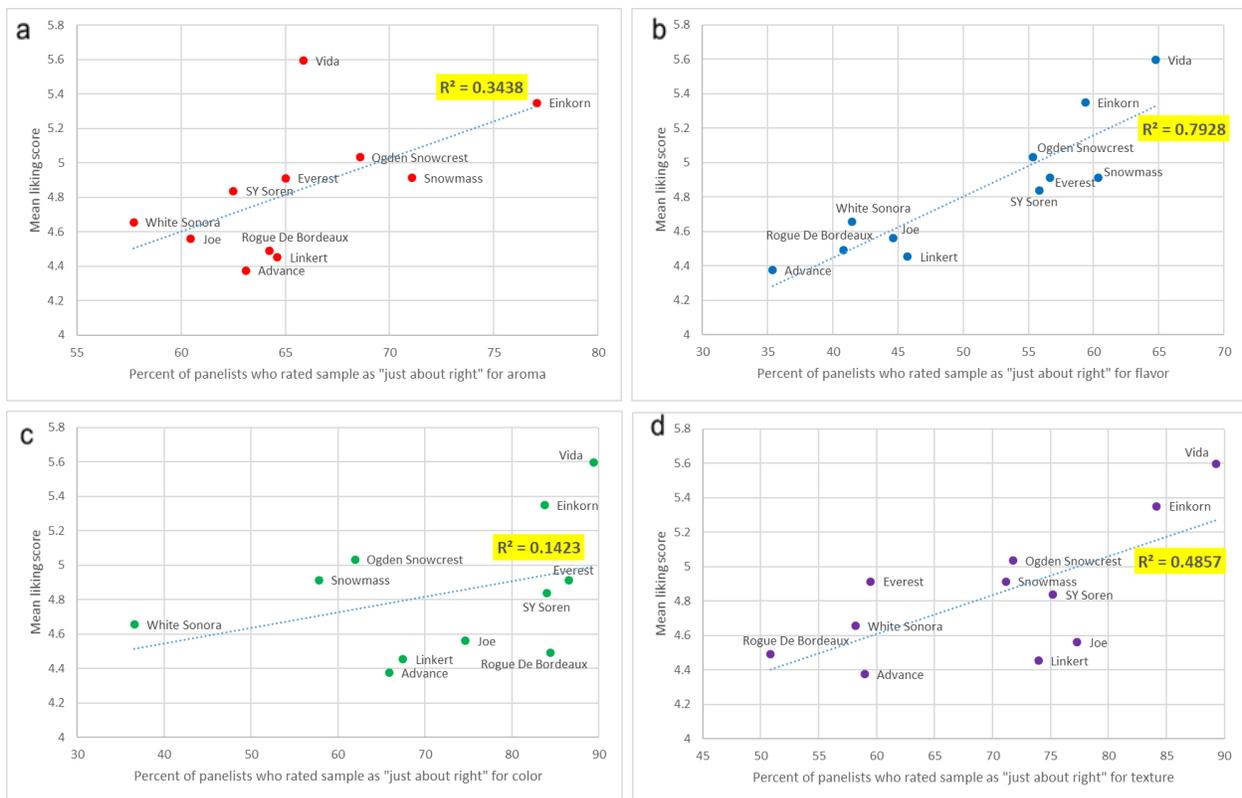


Figure 4a-d. Regression analyses of liking and percent JAR ratings for a.) Aroma b.) Flavor c.) Color and d.) Texture attributes of whole wheat breads. Note that the x-axis ranges differ between figures a, b, c and d.

Conclusion

Breads made using different types of whole wheat flour produced significantly different liking scores, and the most liked sample (Vida) had the highest percent of just-about-right ratings when averaged across its aroma, flavor, color, and texture. Average liking scores were positively correlated with percent JAR scores across all categories, but the relationship was stronger for aroma, flavor, and texture than it was for color. In comparison to breads made from refined flour, the bitter flavors commonly found in whole wheat breads serve as a significant barrier to their consumption by the general public. Development of new whole wheat breads with improved palatability could be an effective method to encourage increased consumption of whole grains in the United States, the long-term inadequacy of which has been associated with increased rates of

many chronic diseases. The data presented in this paper support such development by providing insight into what types of flour produce breads that are most liked by consumers, as well as which sensory attributes need additional focus in future research. This work is limited in that recruited panelists were regular consumers of whole wheat bread, and some response sets were incomplete leading to a smaller usable sample size. Potential future research could include panelists who do not regularly consume whole wheat bread, to see if these novel flour types may be palatable enough for consumers who typically eat refined grain products.

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Appendix A. Complete question set administered to subjects at each testing period.

1. Desire Training

- A part of this study will be measuring how much you want a product by the number of times you press the spacebar over the course of 10 seconds.
- To practice this, you will be shown 2 pictures. Once the screen changes to “press spacebar”, hit the spacebar to indicate how much you would like to consume that product.



Chocolate chip cookie image

“Press spacebar” (the count was captured by the software)



Broccoli image

“Press spacebar” (the count was captured by the software)

2. Hunger Rating

Please rate your current level of hunger.

Options: not at all hungry, somewhat hungry, hungry, very hungry, extremely hungry

3. Desire Measurement

- In today’s study, you will be trying 3 (or 4) samples of bread. Before receiving the sample, you will be shown a picture of the bread and asked to indicate how much you would like to eat it. Then the sample will be delivered to you and you will answer some questions about it.



Bread image

How much do you want to eat this sample?

Options: Not at all, not really, somewhat would like to, would like to, very much would like to

Implicit Desire Measurement

- When the screen changes to “press spacebar”, please press the spacebar to indicate how much you would like to eat the product.



Bread image

“Press spacebar” (the count was captured by the software)

4. Product Specific Questions

How much do you expect to like this product?

Options: Extremely dislike, somewhat dislike, neither like nor dislike, somewhat like, extremely like

Initial liking

Options: 1 (least), 2, 3, 4, 5, 6, 7, 8, 9 (most)

Aroma

Options: Much too weak, too weak, just about right, too strong, much too strong

Flavor

Options: Much too weak, too weak, just about right, too strong, much too strong

Color

Options: Much too light, too light, just about right, too dark, much too dark

Texture

Options: Much too soft, too soft, just about right, too hard, much too hard

How satisfied were you with this bread?

Options: Extremely unsatisfied, somewhat unsatisfied, neither satisfied nor unsatisfied, somewhat satisfied, extremely satisfied

Did this sample meet your expectations?

Options: Below, met, exceeded

- Steps 3 and 4 were repeated for the remaining bread samples. After the panelist was finished sampling all of the breads, they continued to step 5.

5. Engagement Questionnaire

- *I was distracted*
- *I felt myself zoning out during the task*
- *I lost interest in the task*
- *I wanted to devote my full attention to the task*
- *I found the task meaningful*
- *I felt dedicated to finish the task*
- *My contribution was significant to the outcome of the task*
- *I was motivated to expend extra effort during the task*
- *I found the task captivating*
- *During the task I was enjoying myself*

All above statements had the following options:

Strongly disagree, disagree, somewhat disagree, neither agree nor disagree, somewhat agree, agree, strongly agree

Appendix B. Complete set of JAR data for all bread samples plotted on histograms

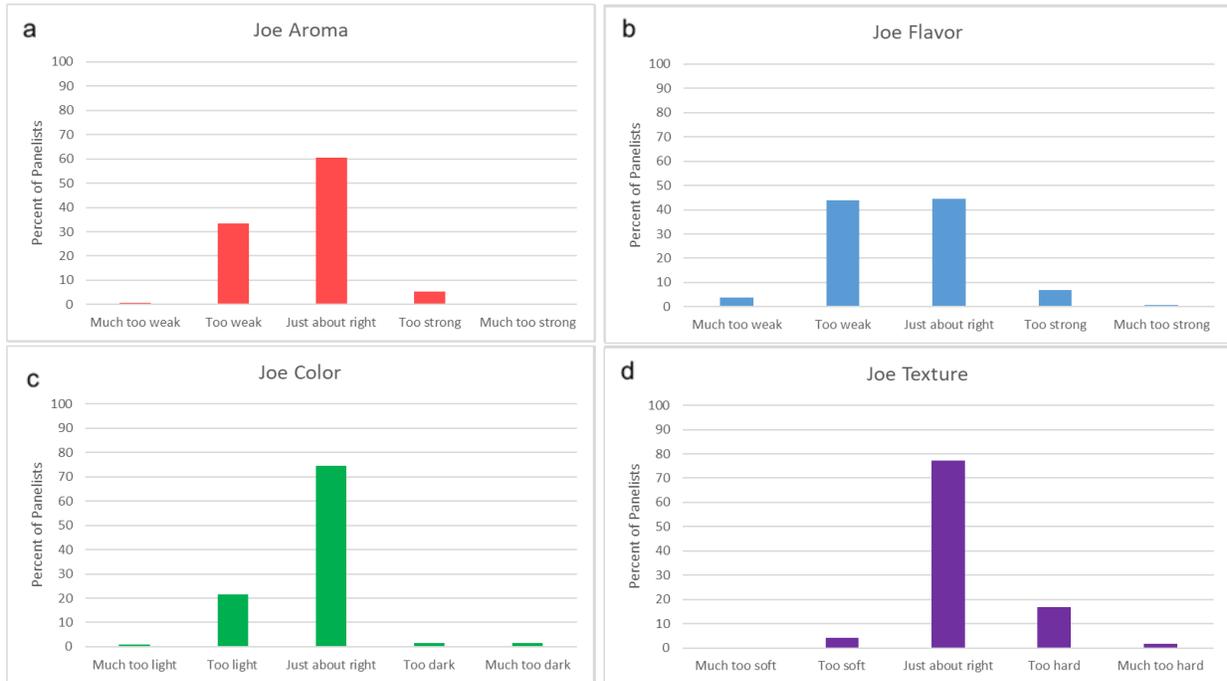


Figure 5a-d. Distributions of just-about-right (JAR) ratings for a.) Aroma (n=129) b.) Flavor (n=130) c.) Color (n=130) and d.) Texture (n=119) attributes of whole wheat bread made using Joe flour.

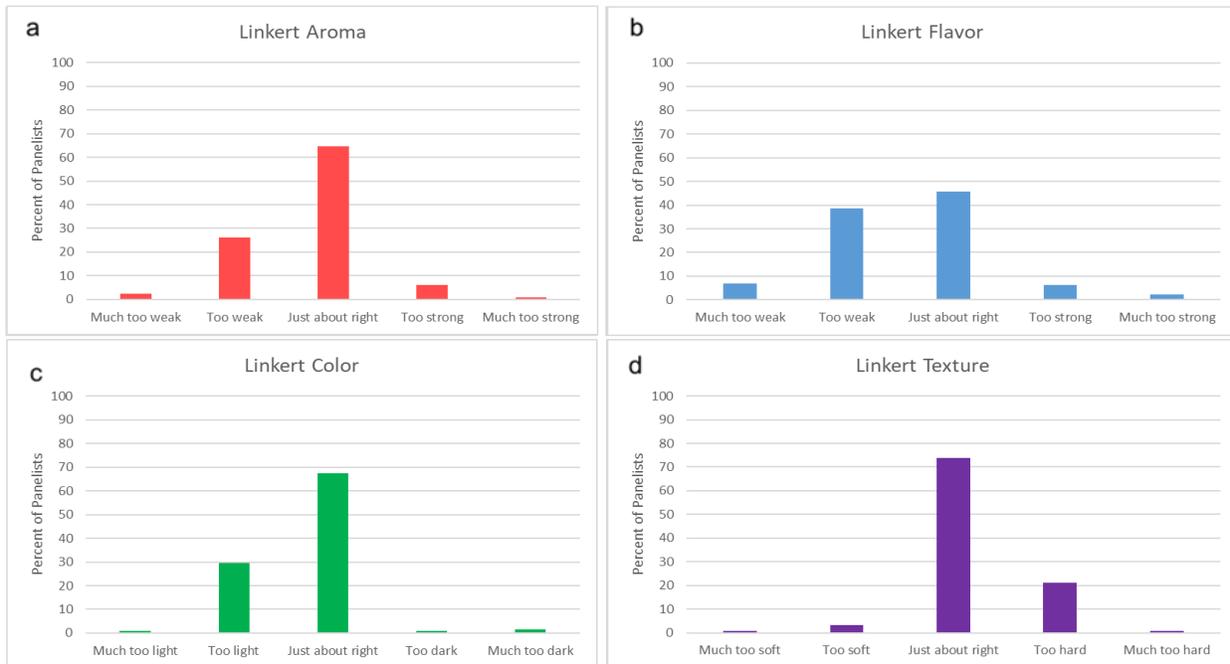


Figure 6a-d. Distributions of just-about-right (JAR) ratings for a.) Aroma (n=130) b.) Flavor (n=129) c.) Color (n=129) and d.) Texture (n=119) attributes of whole wheat bread made using Linkert flour.

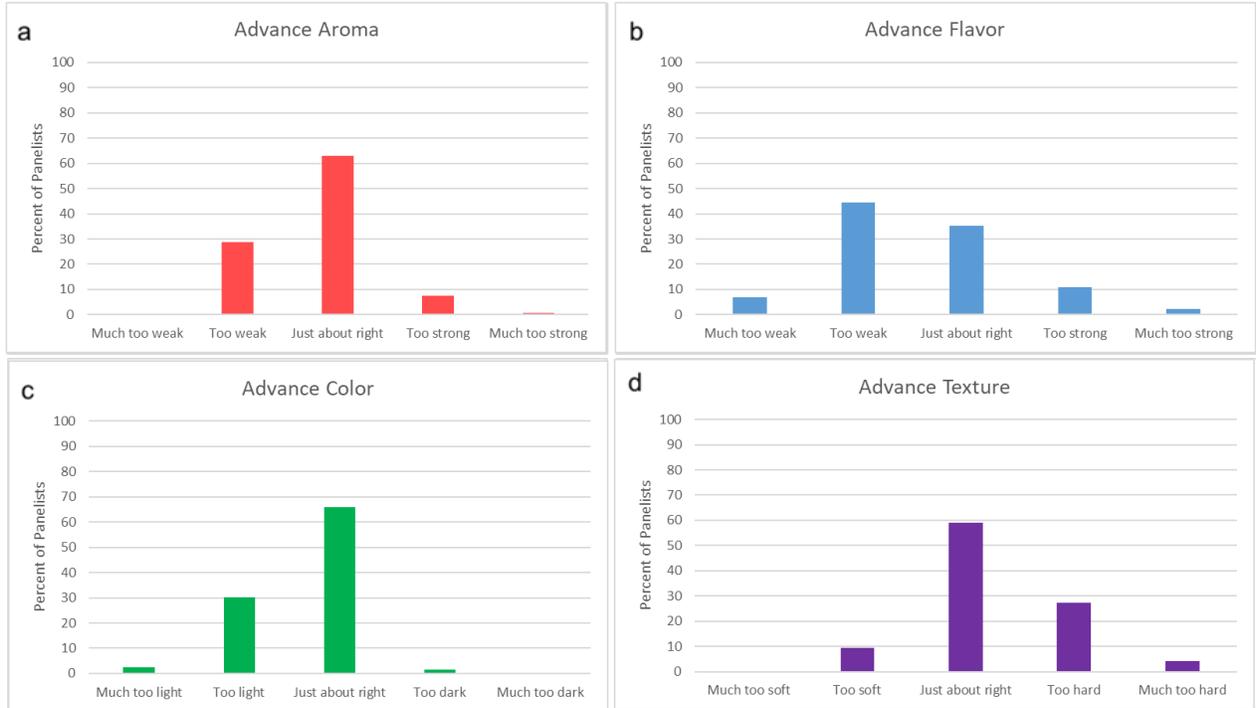


Figure 7a-d. Distributions of just-about-right (JAR) ratings for a.) Aroma (n=122) b.) Flavor (n=130) c.) Color (n=129) and d.) Texture (n=117) attributes of whole wheat bread made using Advance flour.

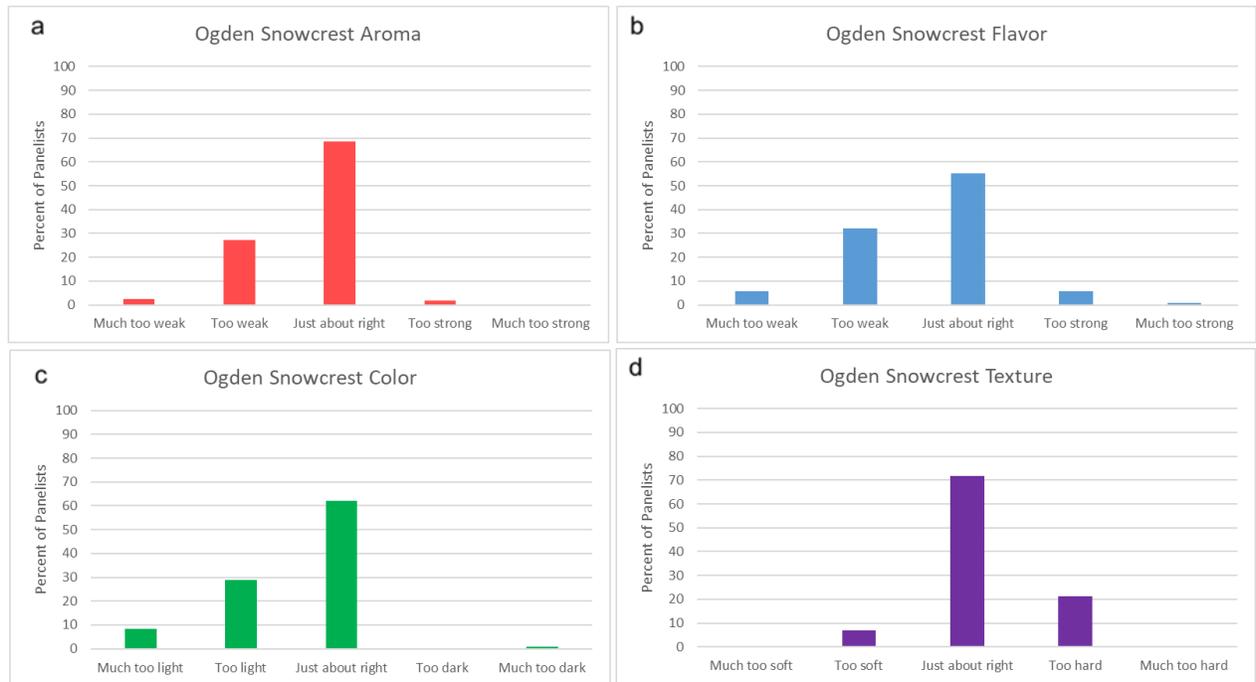


Figure 8a-d. Distributions of just-about-right (JAR) ratings for a.) Aroma (n=121) b.) Flavor (n=121) c.) Color (n=121) and d.) Texture (n=117) attributes of whole wheat bread made using Ogden Snowcrest flour.

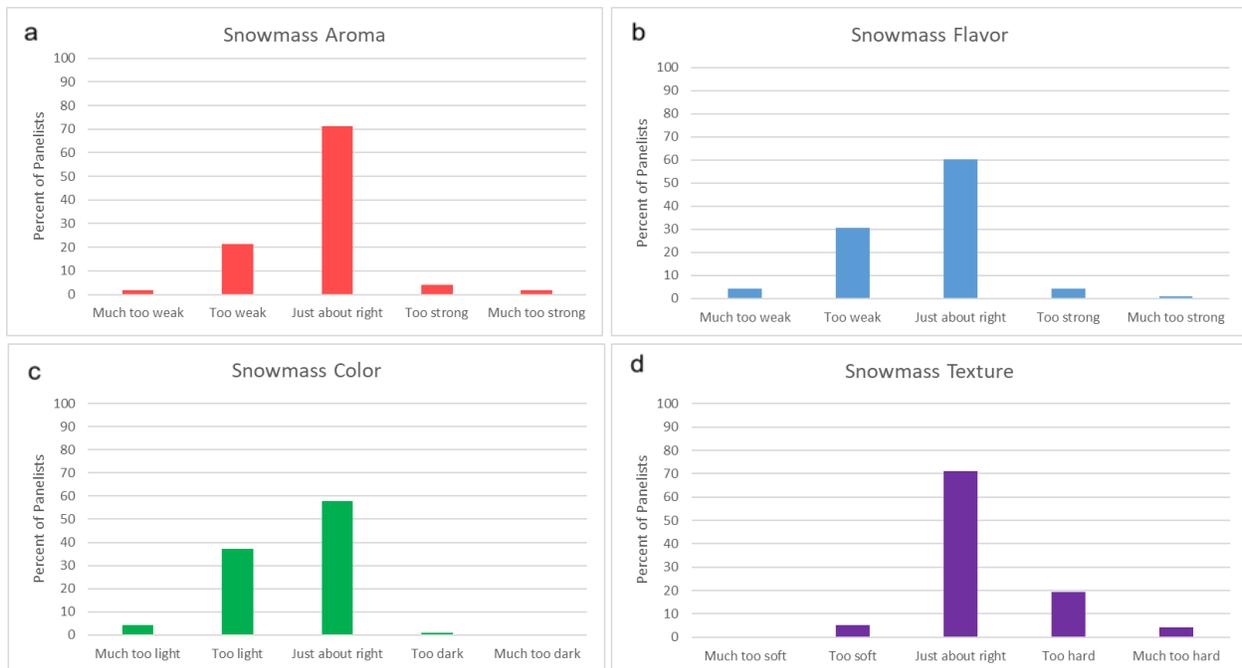


Figure 9a-d. Distributions of just-about-right (JAR) ratings for a.) Aroma (n=121) b.) Flavor (n=121) c.) Color (n=121) and d.) Texture (n=118) attributes of whole wheat bread made using Snowmass flour.

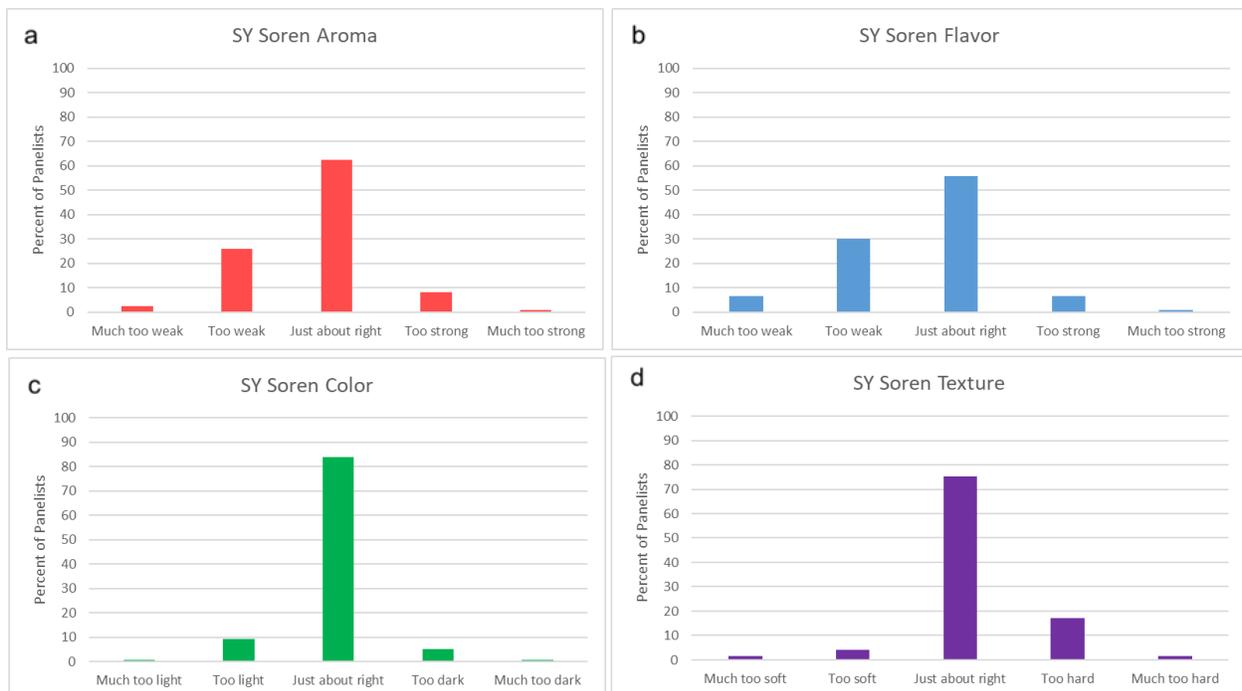


Figure 10a-d. Distributions of just-about-right (JAR) ratings for a.) Aroma (n=120) b.) Flavor (n=120) c.) Color (n=119) and d.) Texture (n=117) attributes of whole wheat bread made using SY Soren flour.

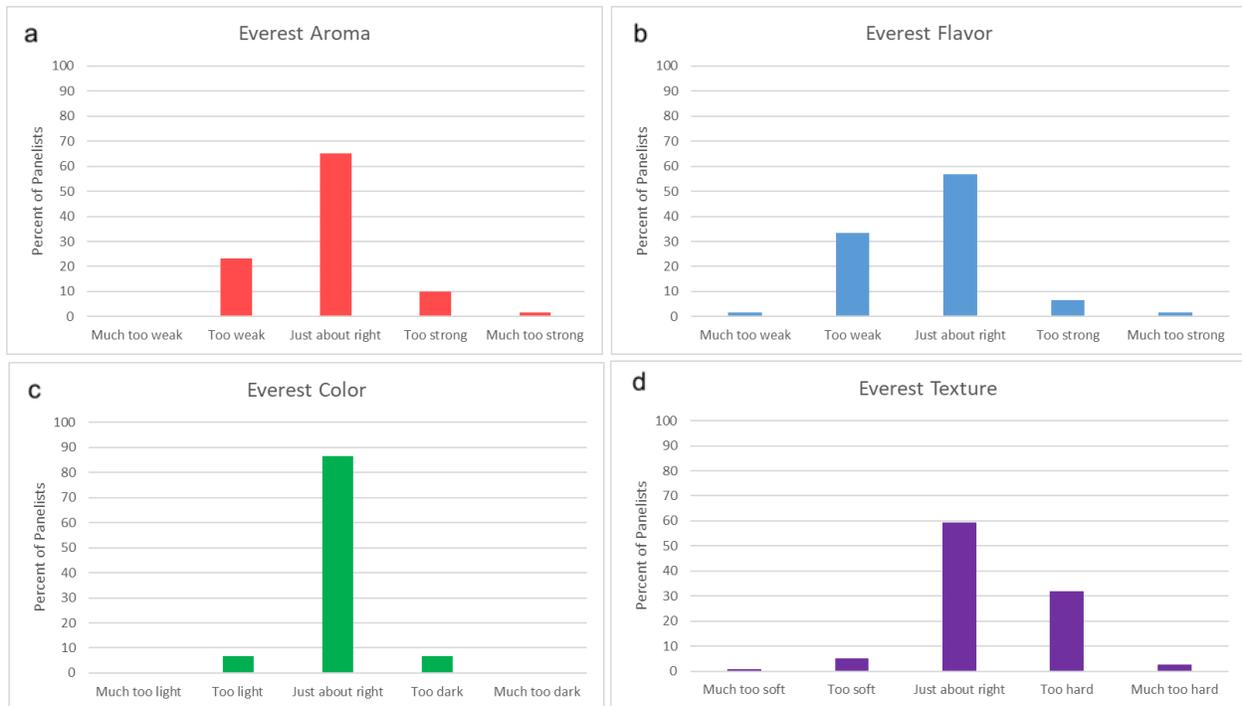


Figure 11a-d. Distributions of just-about-right (JAR) ratings for a.) Aroma (n=120) b.) Flavor (n=120) c.) Color (n=119) and d.) Texture (n=116) attributes of whole wheat bread made using Everest flour.

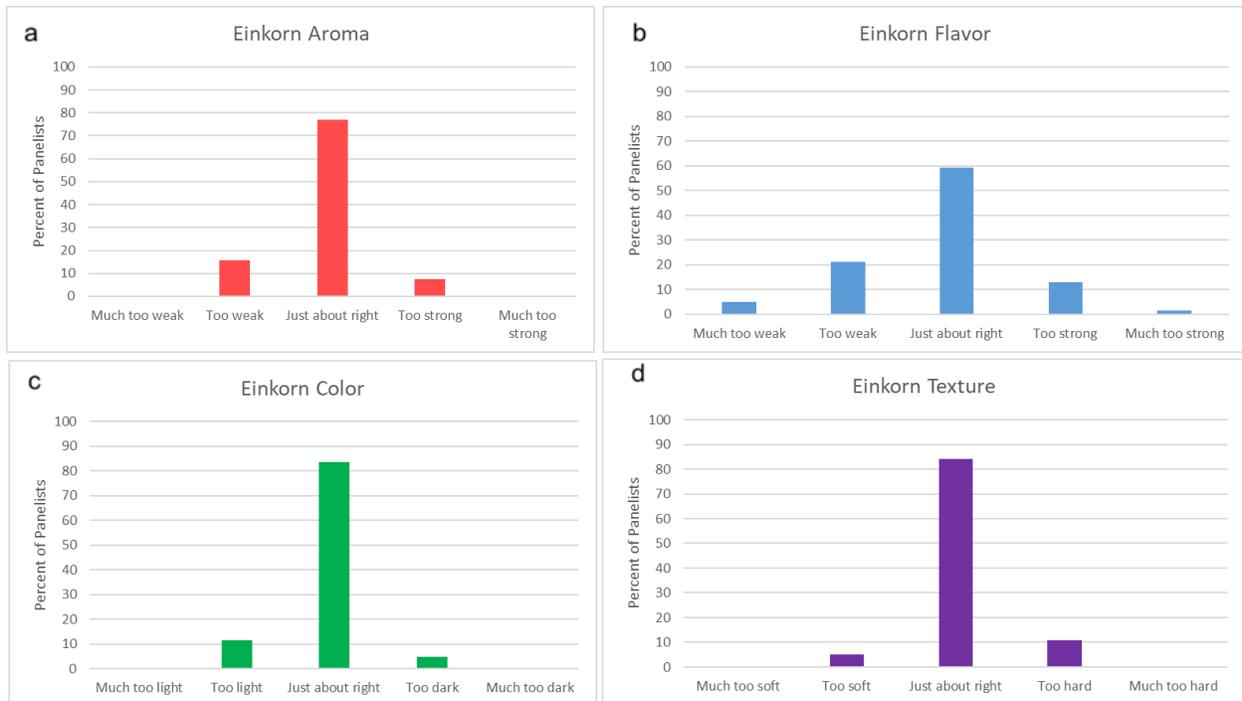


Figure 12a-d. Distributions of just-about-right (JAR) ratings for a.) Aroma (n=122) b.) Flavor (n=123) c.) Color (n=123) and d.) Texture (n=120) attributes of whole wheat bread made using Einkorn flour.

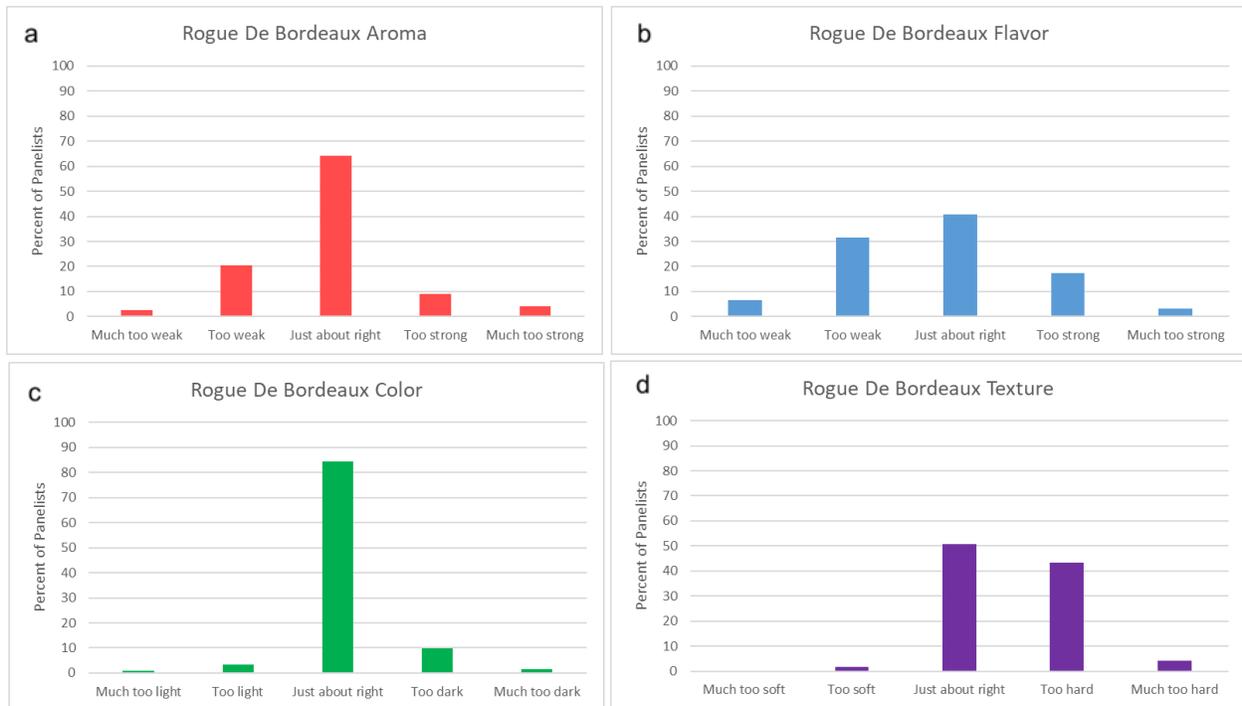


Figure 13a-d. Distributions of just-about-right (JAR) ratings for a.) Aroma (n=123) b.) Flavor (n=120) c.) Color (n=122) and d.) Texture (n=120) attributes of whole wheat bread made using Rogue De Bordeaux flour.

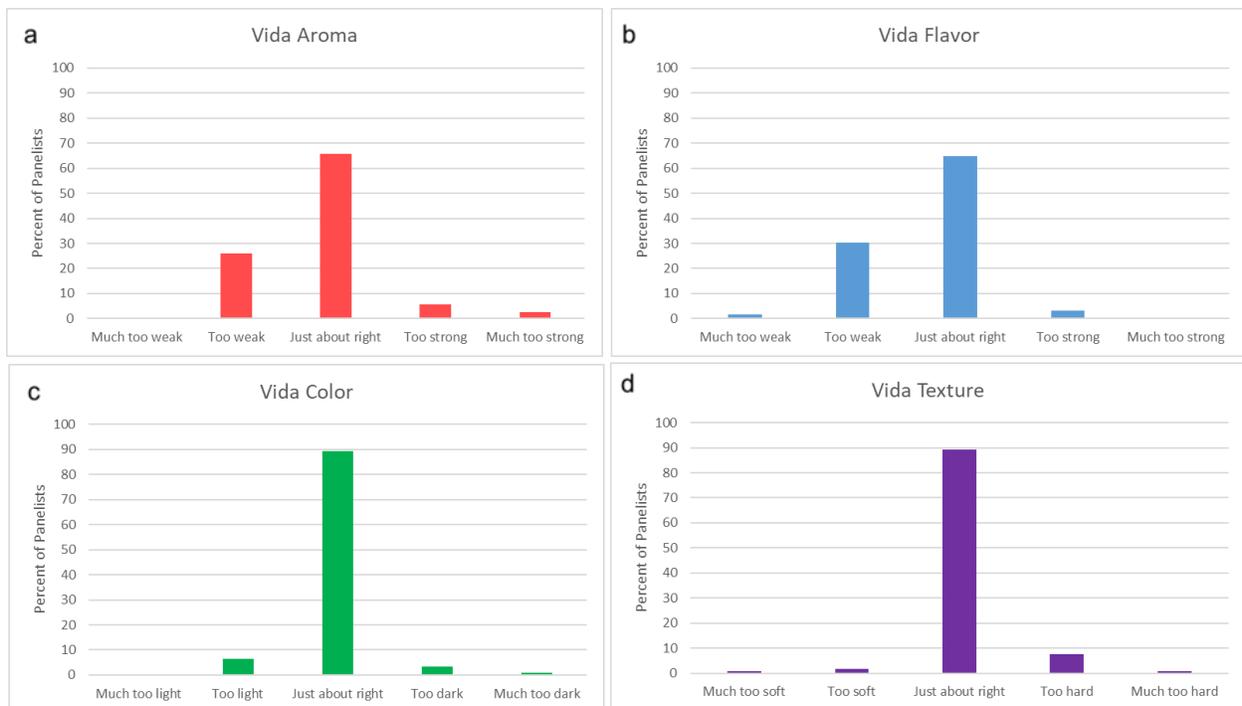


Figure 14a-d. Distributions of just-about-right (JAR) ratings for a.) Aroma (n=123) b.) Flavor (n=122) c.) Color (n=123) and d.) Texture (n=121) attributes of whole wheat bread made using Vida flour.

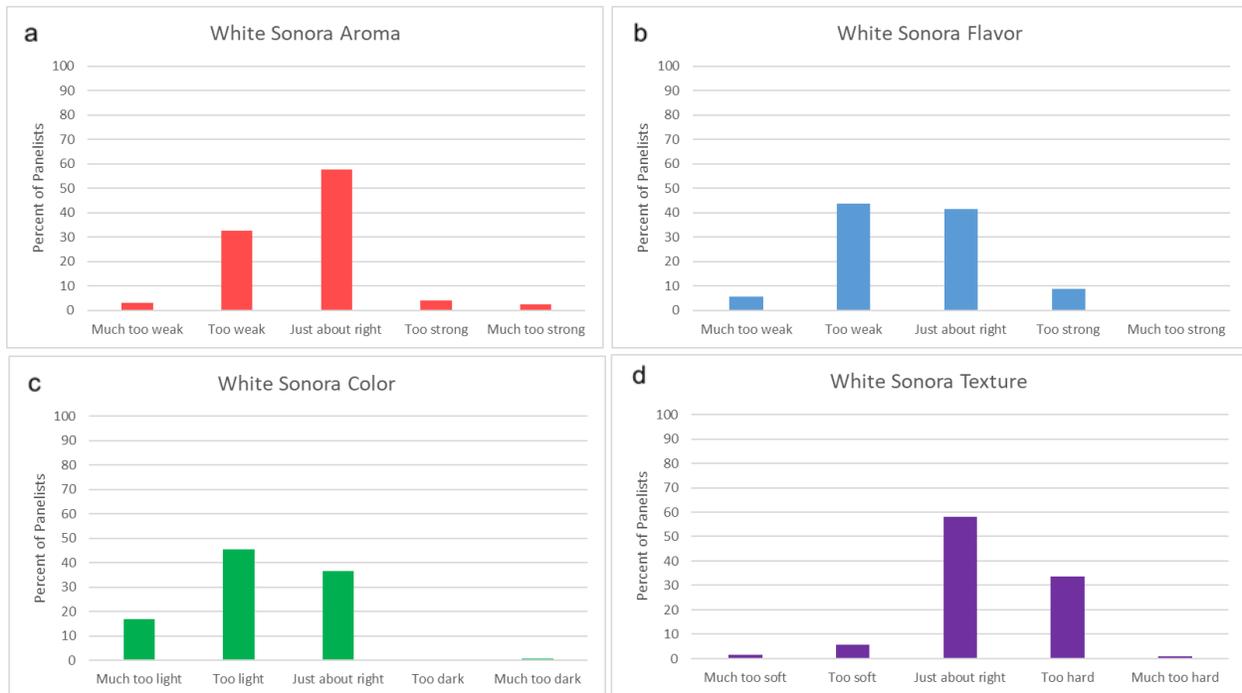


Figure 15a-d. Distributions of just-about-right (JAR) ratings for a.) Aroma (n=123) b.) Flavor (n=123) c.) Color (n=123) and d.) Texture (n=122) attributes of whole wheat bread made using White Sonora flour.