THE INSTRUMENTAL TEXTURE, DESCIPTIVE SENSORY PROFILE, AND OVERALL CONSUMER ACCEPTANCE OF LENTIL-ENRICHED CRACKERS

by

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ABSTRACT

Lentil-enriched crackers were formulated using local Montana wheat flour and red Petite Crimson lentils. Variables of the cracker formulations included different lentil to wheat flour weight ratios (0/100, 50/50, 100/0) and pre-roasting times of the lentil flours (0- 10 minutes at 176 degrees Celsius). Texture analysis revealed increase in lentil to wheat ratios from 0/100 to 100/0 increased the hardness, stiffness, toughness, and crunchiness of the crackers, and the increase in time of lentil pre-roasting from 5 to 10 minutes reduced the hardness, stiffness, and toughness ($P < 0.05$). Quantitative descriptive analysis (QDA) revealed that the lentil-enriched crackers are described by beany aroma and aroma-by-mouth, umami taste and aftertaste, and crunchy texture. The consumer test revealed that increase in lentil to wheat ratios from 0/100 to 100/0 decreased the liking of the crackers ($P < 0.05$), and pre-roasting of lentils did not cause any difference. This study can provide insight on how interactions between texture, sensory profile and sustainability labels affect lentil-enriched crackers. The outcome can direct future lentil cracker development and marketing efforts to promote local value-added agriculture.

INTRODUCTION

Lentils (*Lens culinaris*) are annual indigenous plants originating in various parts of the world including Western Asian and North America (Ganesan & Xu, 2017), and are are a good source of protein, fiber, complex carbohydrates, vitamins and minerals (Yadav et al., 2007). Besides these nutritional and health benefits, they are sustainable and beneficial to the environment because lentils are a drought enduring plant (Joshi et al., 2017) that fixates nitrogen back into the soil, helping limit the usage of synthetic nitrogen and greenhouse gas emissions (Chen et al., 2012).

Montana is the largest lentil and dry pea producer leading pulse crops in the United States (the dried seed of legumes such as lentils, chickpeas, beans, peas) (USDA, 2019). While most of these Montana pulse crops are for export, Innovative lentil products such as crackers and sauce dips (Lakkaukula et al., 2017), focusing on domestic consumption, have been introduced to the U.S. market. Particularly, consumers have increasingly demand pulses and relevant products since 2008. Accordingly, pulses consumption in the U.S. is predicted to be increased (Lakkakula et al., 2017)   With the rise of novel lentil products; for example, snacks, soups, and pasta made from lentils are popular in consumer (Lakkaukula et al., 2017), it is important to understand what can motivate consumers to purchase lentil products.. As taste being the long-lasting top driver for food purchase (IFIC Foundation, 2019), sensory evaluation has been utilized to determine the overall consumer acceptance of current lentil and pulse containing snack products in development (Lazou et al., 2010; Millar et al., 2017; Tiwari et al., 2011; and Ryland et al., 2010). Sensory studies on pulse-enriched crackers often involve gluten-free flours such as buckwheat (Sedej et al., 2010) and other pulses and beans such as chickpeas (Kohajdová et al., 2011) and pigeon pea (Tiwari et al., 2011). Most of the previous literature on lentil sensory evaluations involve crackers, biscuits extruded puffs or nutrition bar products (Lazou et al., 2010; Millar et al., 2017; Tiwari et al., 2011; and Ryland et al., 2010). Abu-Ghoush et al. (2014) studied the nutrition, consumer acceptance, and descriptive sensory properties of extruded soy-wheat-lentil analog products. Ryland et al. (2009) utilized a descriptive panel and external preference mapping to relate the intensity of various descriptive sensory attributes in a micronized lentil flake snack bar product. Pulse enrichment often leads to increase in product hardness, a key texture challenge in developing pulse snacks (Lazou et al., 2010). Literature is yet to be established to navigate the sensory acceptance and descriptive sensory properties of lentil-enriched crackers in the dimension of product texture.

Labeling can also impact a consumer’s willingness to buy a product. Healthfulness has been the main drivers in food purchase (IFIC Foundation, 2019). Plus, three-quarter of millennials, the largest spending power since 2018, are willing to pay a premium for sustainability (Nielsen, 2015). Due to lentils being nutritious as well as environmentally friendly, adding lentils into novel food products with effective labeling could create a successful product on the market since there is an increasing number of consumers expressing interests to purchase food products with health and sustainable features (IFIC Foundation, 2019; Nielsen, 2015). Lentils and pulses have been used to produce extruded snacks, bar snack products, and most popular, pasta products which are marketed as gluten free, fiber, protein, and micronutrients rich (Ryland et al., 2010; Morales et al., 2015; Bouasla et al., 2017). Out of the 4,922 pulse-containing food products launched in

North America between 2006 and 2016, a significant number carried health-related, but none of these pulse products bear a claim to inform consumers the environmental benefits of pulses (AAFC, 2017). Consumers have expressed struggles in recognizing environmentally sustainable products, suggesting the need to investigate impact on food purchase by environmental claims such as carbon footprint (IFCC,2019).

Past research found that sustainability, social welfare and eco-friendly claims positively affected a consumer's overall liking and purchase intent on fair-trade chocolate bars, produce and household cleaning products (Hwang et al., 2016; Bjørner, 2003). Furthermore, Hwang, et al. (2016) found that consumers are more likely to give a product a higher quality rating on more descriptively labeled items than regular labeled items Additionally, in a study determining how certain health and environmental claims affect the consumer's willingness to pay for different pulse pasta products revealed that a combination of environmental and health claims received the most significant impact on increasing one's willingness to pay for the product (Lemken et al., 2017). As for carbon footprint labeling specifically, past studies have discovered that carbon labels are often most effective when consumers are specifically identifying climate friendly products (Emberger-Klein and Menrad 2017), and that carbon emission labeling is more of a reminder to consumers of what their set standard carbon emission levels is acceptable in a product (Camilleri et al., 2019). Furthermore, previous attempts of implementing carbon footprint labeling in large supermarket retailers such as Tesco, have failed due to consumers' lack of knowledge of the topic and the greenhouse gas emissions number being too abstract for most consumers to interpret (Mereyding et al., 2019). The same study found that price was still the largest determining factor when purchasing food and that negative labeling may be more effective than positive labeling to deter consumers from buying not as environmentally friendly products (Mereyding et al., 2019). However, there is still little research on sustainability claims and labeling for lentil products, and how labeling potentially interacted with product descriptive sensory qualities.

Local labeling funded by state agriculture programs are becoming more common, and the effectiveness of these local marketing tactics vary depending on the state's efforts towards establishing quality and certification guidelines to allow local food businesses to utilize the local seal (Onken and Bernard, 2010). The higher the quality, longer the program has been established and larger promotion of these products by the state have had greater success in both consumer awareness that these programs exist and sales (Onken and Bernard, 2010). Currently, Montana has established the "Grown in Montana", "Made in Montana" and "Native American Made in Montana" labels for food and cosmetic products (Made in Montana, 2017). Requirements to qualify a product being "Made in Montana" is that the products must be grown, created, made or enhanced in the state of Montana resulting in 50% or more in added-value (Made in Montana, 2017). To the best of our knowledge there are few studies that investigate the effectiveness of local labeling, and so far there are no studies evaluating the effectiveness of the Made in Montana logo for local Montanan producers.

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Therefore, this study aimed to analyze the overall consumer acceptance related to labeling, instrumental texture and descriptive sensory properties of lentil-enriched cracker. Studying these factors of a lentil cracker product could create another healthy and sustainable snack alternative on the market while also supporting local Montana lentil producers. In addition to creating a healthy and sustainable snack that consumers enjoy, studying the consumers' perceptions of labeling on these products can also potentially create a new market for sustainable snack food products. Ultimately, supporting consumers' health, the economy and the environment.

MATERIALS AND METHODS

Materials

Red lentils were obtained from Timeless Seeds (Ulm, MT) and organic all-purpose wheat flour was obtained from Wheat Montana (Great Falls, MT). Salt, sugar, baking powder, olive oil, and xanthan gum were purchased from local grocery stores.

Preparation of The Lentil-enriched Crackers

The red lentils were milled into a red lentil flour using the Wondermill Grain Grinder (Grote Molen Inc, Pocatello, ID). Pre-roasted red lentil flour was spread in a thin layer on a baking sheet and baked at 176°C for five minutes or ten minutes.

The cracker formulation was modified from a previous study (Turker et al., *in preparation*). Seven different cracker formulations were prepared using measurements shown in Table 1. The lentil flour with 0, 5, or 10 minutes of pre-roasting was used to replace 0, 50, or 100 percent of the all-purpose flour. The moisture content of each of the ingredients was measured, and the amount of each ingredient in each recipe was adjusted to reach the same total moisture content of mixture across the seven formulations. The lentil flour, all-purpose flour, sugar, salt, and baking powder were mixed together first. The Xanthan gum was mixed in water, which was then mixed with the olive oil. The dry and wet ingredients were mixed together by hand until a homogenous dough was formed. The dough then rested at room temperature for fifteen minutes wrapped in a plastic wrap. The dough was then rolled through a pasta machine (Marcato, City, Italy) on the 0.9 mm thickness setting twice and cut into 1-inch squares. Four rows of holes were then punctured into crackers using a fork to allow steam to escape while baking. Crackers were baked at 176°C for a total of eleven minutes in a convection oven, rotating the pan 180 degrees halfway through at 6 minutes and then continued to bake for the last 5 minutes. The crackers were then cooled on the baking tray.

Instrumental Texture Analysis

The texture properties of the cracker samples were measured using TA.XTPlus texture analyzer and software (Texture Technologies, La Crescenta, CA). The texture analyzer used a 10 mm-diameter probe of the TA-25C Three Fixture Crunchiness Set and a 50 kg load cell.

The texture analyzer force was calibrated using a two-kilogram weight. The height was calibrated to a distance 30mm with a contact force of 15g. Crackers were stacked in threes and placed on the platform of the texture analyzer upside down. The compression test settings were 1.0 mm/s compression speed, 10 mm/s post-test speed, and 5 mm compression distance (at 16.6% deformation). The toughness, hardness, stiffness, and crunchiness were calculated based on area under the curve (kg.s), peak force (kg), slope (g/s) and, jagged-smooth ratio which is the ratio of the length of the smoothed curve to that of the actual curve (%) (Texture Technologies, 2010), respectively, on the force-time graph. Fifteen measurements were made for each batch preparation of the crackers, and three batches were made for each cracker recipe.

Quantitative Descriptive Analysis

The QDA was approved by MSU IRB (approval number W-YK030419-EX). The QDA panel consisted of 27 training sessions and 3 test sessions. Each session ran for an hour. The first 11 training sessions were used for term generation and definitions, with 3 sessions of term-generation, 5 sessions of term-refinement and 3 sessions of term-finalization. Table 2 lists the finalized attributes and the corresponding definitions, references, evaluation protocols for each modality (aroma, aroma-by-mouth, taste, aftertaste and texture). The panel also determined the rinse protocol between each cracker tasting to be in the order of carbonated water, warm and room temperature water.

Term generation was followed by 10 sessions of reference anchoring and group scoring practice. During the reference anchoring, panelists were asked to suggest commercial references for each attribute that would be an 8 – 10 in intensity out of the 0-15 linear scale. During group scoring practice the panel decided which samples were strongest and weakest in intensity for each attribute. The weakest sample being 0 and the strongest sample being 15 on a linear scale ranging from 0-15. They then decided the rest of the sample intensities using the strongest and weakest sample as well as the reference as their anchors. For each attribute, the panelists then calibrated their own rating against the group average rating. The group focused on one modality per session during group scoring practice and then were asked to rate for all modalities in the 19th, 20th and 21st sessions as a group. Throughout these group sessions, panelists were trained to eat ½ of a cracker by biting into to break and then chew normally until before the samples were ready to be swallowed but spit out before being swallowed.

Following the group scoring practices, there were 6 individual booth practice sessions where panelists practiced rating all modalities. The booth sessions were carried out under incandescent lighting at 25°C in Hannon Hall at Montana State University Bozeman's campus. Compusense Cloud (Compusense, Guelph, Ontario, Canada) was used for the data collection. Prior to each booth session the panelists used the references to familiarize themselves with each attribute in each modality. The panelists were allowed to use reference lists and definitions and leave the booth to re-visit each reference at any time during the evaluations. During each practice session, each panelist was given 3 of each cracker formulation (Table 1). Among the 3 crackers, 1 cracker was used to evaluate aroma by mouth (½ cracker at a time), 2 crackers were first used uneaten to evaluate visual and aroma, then ½ a cracker was used to evaluate taste and aftertaste, and 1 and ½ cracker was used to evaluate the texture (½ cracker for 3 attributes). After each of the 6 individual practice sessions, the panelists were provided feedback with their own ratings and group averages from each practice session. Following the individual booth practice sessions, there were 3 final booth test sessions in which the protocol for individual booth practices were the same, except the data was not revealed to the panelists.

Overall Consumer Acceptance Test

The consumer acceptance test was approved by the Montana State University Institutional Review Board (MSU IRB, approval number W-YK030419-EX) and took place at the Hannon Culinary Art classroom (Bozeman, MT). One hundred and eight adults age 18-years or older, who self-declared to have no dietary restrictions were recruited. The panelists filled out a survey asking their age, gender, and the place where they have lived for the longest time. Fifteen different samples were tested in a one-hour time frame. Control, no pre-roasted lentil flour and ten-minute pre-roasted lentil flour cracker formulations (Table 1) were presented in three different labeling conditions, including no label, with a low-carbon footprint label, and with a Made in Montana label on the ballot (Figure 1). Each sample was assigned a random three-digit code and four different ballots with different orders of sample presentations were randomly assigned to the panelists. Panelists were asked to rinse with carbonated water, warm water and then room temperature water before tasting each sample and were asked to either swallow all samples and rinses or spit out all samples and rinses to ensure that their tasting methods were consistent. After tasting each sample, they were asked to rate it using an interval nine-point hedonic scale with "Extremely dislike", "Neither like or dislike", and" Extremely like" as its anchors for scores 1, 5, and 9, respectively. Panelists are then asked to stop tasting and wait five minutes in-between every five samples to minimize fatigue.

Statistical Analyses

XLSTAT 2020.1 (Addinsoft Inc, New York, NY) was used to analyze the data. One-way Analysis of Variance (ANOVA) and Fisher's least significant difference (LSD) test were used to detect significant differences among sample means (α = 0.05). F-value and F_{adj} values were calculated to determine the significance of between sample*panelist factors. The adjusted F-value was calculated as F_{adj} = [sample mean square]/[sample*panelist mean square]. Principal component analysis (PCA) was used to visualize the QDA variables on a biplot, to visualize the QDA texture and instrumental texture properties on a biplot, and to visualize the consumers on a bi-plot relative to the products. Agglomerative hierarchical clustering was used to identify clusters among the samples in the QDA data.

Tables and Figures

Table 1. The Formulation and Coding of the Lentil-enriched Crackers.

Sample code[a]	Lentil flour pre-roasting time (min)	Lentil flour/ wheat flour ratio (w/w, d.b.)[b]	Ingredient weight (g, w.b.)[c]			
			Red lentil flour	All-purpose flour	Water	Xanthan gum
Control	-	0/100	0.0	100.0	33.0	0.0
0R50L	0	50/50	49.0	50.0	33.0	0.3
0R100L	0	100/0	100.0	0.0	34.7	0.6
5R50L	5	50/50	46.0	50.0	33.0	0.3
5R100L	5	100/0	100.0	0.0	40.8	0.6
10R50L	10	50/50	47.0	50.0	33.0	0.3
10R100L	10	100/0	100.0	0.0	44.3	0.6

[a] The samples were coded with lentil pre-roasting treatment by minutes and the percentage of lentil flour used. For example 0R100L indicates the cracker was made from lentil flour pre-roasted for 0 min (non-roasted lentil flour) with 100 percent lentil flour.
[b] The ratios of the flours were on a dry weight basis. The water amount was then adjusted based on the moisture content of the flours to achieve the same total moisture content in the dough across the formulations.
[c] The ingredients were weighed by a wet basis. The formulation also included, on a wet base, 20 grams of olive oil, 2 grams of salt, 1.5 grams of sugar, and 0.6 grams of baking powder.

Table 2. The Terms, References, and Definitions for the Attributes of the Lentil-enriched Crackers Generated by the Quantitative Descriptive Analysis Panel.

Modality	Term	Reference Item	Reference Score	Definition
Visual	Saturated Orange	Goldfish Cracker	7.8	The amount of orange hue
	Puffy	Mini Cheese Ritz top cracker only	8.6	Uneven, pillow-looking
	Thick	Wheat Thin	8.3	Lateral thickness of the cracker
Aroma	Floury	Unsalted saltine cracker	8.8	The aroma of an unsalted saltine crackers
	Beany	Roasted soybeans	7.6	The aroma of soybeans
	Roasted legume-y	5 min-roasted lentil flour	8.1	The aroma of roasted lentil flour
	Buttery popcorn	Popcorn	10.6	The aroma of buttery popcorn
	Cheesy	Cheez-It	8.9	The aroma of a Cheez-It
Aromaby-mouth	Beany	Veggie straw	10.0	The aroma by mouth of veggie straws
	Cheesy	Cheez-It	7.0	The aroma by mouth of Cheez-It
	Floury	0.6% (w/v) flour in water	8.2	The aroma by mouth of flour
	Saltiney	Unsalted saltine cracker	8.0	The aroma by mouth of a unsalted saltine cracker
	Baked	Goldfish Cracker	9.0	The aroma by mouth of a baked cracker
Taste	Salty	0.26% (w/v) sea salt in water	9.8	Taste of sodium chloride
	Bitter	Burnt toast	9.0	Taste of burnt toast
Aftertaste	Umami	0.3% (v/v) soy sauce in water	10.8	After taste of soy sauce
	Salty	0.26% (w/v) sea salt in water	9.0	After taste of sodium chloride
	Beany	Veggie straws	9.0	Aftertaste of veggie straws
	Floury	0.6% (w/v) flour in water	8.2	Aftertaste of flour
Texture	Snappy	Chicken biscuit	9.9	Audible snap when first bitten into
	Easy to Dissolve	Wheat Thins	11.8	Easy to dissolve during the overall chewing
	Tooth packing	Potato chip	8.1	The residual amount of food in molars after chewing and before spitting out
	Crumbly	Ritz Cracker	10.9	Falls apart into thin powder in the first few bites
	Crunchy	Wheat Thins	11.0	During the process of chewing there is an audible noise of chewing
	Gritty	Graham cracker	8.9	The mealy/course residual granule feeling in the mouth after chewing and before spitting out
	Flaky	Ritz Cracker	10.6	Breaks into small, thin, dry layers in the first few bites
	Moisture absorbing	Saltine cracker	10.6	Absorbs saliva and moisture in the mouth while chewing

(a) (b)

Figure 1 – Example of Labeling Effect Logos Presented in Hedonic Scale Sensory Evaluation of Lentil-enriched Crackers: “Low Carbon Footprint” label (a) (Meyerding et al., 2019), and “Made in Montana” label (b) (Montana Department of Commerce, 2017).

RESULTS AND DISCUSSION

Instrumental Texture Properties of the Lentil-enriched Crackers

As seen in Table 3 increased lentil level in the flour mix from 0 to 100% resulted in increased toughness, hardness, and stiffness of the crackers. The increased hardness of the cracker could be attributed to the fact that pulse flours have higher protein content at 22.4 – 25.0 g/100 g and higher fiber content than wheat flour (9.21 – 12.33g/100 g) (Zucco et al., 2011; Millar et al., 2017). However, for crackers with 100% lentil flour, pre-roasting the lentil flour for 10 minutes (10R100L) significantly reduced hardness and stiffness relative to the crackers with non-pre-roasted and 5-minute pre-roasted lentil flour (0R100L and 5R100L). This might be related to the pre-roasting of the lentil flour which caused the lentil starches to expand, resulting in a crisper and softer product (Lazou et al., 2011). Furthermore, samples that contained non-pre-roasted or 10-minute pre-roasted lentil flour (0R50L, 0R100L, 10R50L, and 10R100L) were significantly crunchier than the 100% wheat sample (Control). Crunchiness is related to the water content of foods, it was reported that increasing water content breaks macromolecular interactions and promotes the mobility of side chains and the backbone of these macromolecules, thus decreases the glass transition temperature, stiffness and viscosity of the food (Tunick et al., 2013). Similar study in dry crisp product showed as well that lower moisture content indicated a crunchier and crisper product (Tunick et al, 2013). In our current study, lentil flour contains 8.24 g/100 g of moisture on a wet basis which is lower than wheat flour (13.5-14.5% for wheat moisture) (USDA,2008). This might explain why the non-pre-roasted and ten-minute pre-roasted lentil crackers were crunchier than the wheat cracker. The 5-minute pre-roasting might have enabled a limited level of macromolecular movement within the lentil flour, and, hence, reinforce the strength of the microstructure and did not lead to an increase in crunchiness given the loss of moisture.

Descriptive Sensory Profiles of the Lentil-enriched Crackers

Two statistically significant discriminant functions were found, explaining 96.5% of the variability, with F1 and F2 contributing 92.1% and 4.4%, respectively (Figure 2). Agglomerative hierarchical clustering based on the QDA data revealed three groups of the crackers. The crackers with 100% lentil formed a group and shared the sensorial attribute of the Saturated orange visual being positively correlated to a series of terms in aroma, aroma-by-mouth, taste, and aftertaste including Beany, Roasted legumey, Cheesy, Baked, Umami, and Bitter (Figure 2 and Table 7). On the opposite side of the Saturated orange vector was the control sample, featured with Puffy and Thick visual, Saltiney aroma-by-mouth, and Floury aroma, aroma-by-mouth, and aftertaste (Tables 4 and 5). The crackers with 50% lentil formed a group and situated in between the above two groups. The length of lentil flour pre-roasting did not have a pronounced impact on the sample distribution along the vector of Saturated orange. Instead, at the same level of lentil in the cracker, pre-roasting shifted the crackers toward the positive end of the Crunchy and Gritty vectors.

<u>Visual, Aroma, Aroma-by-Mouth, Taste, and Aftertaste</u>

The three crackers of 100% lentil showed significantly higher intensities in the beany aroma and aroma-by-mouth compared to other samples (Tables 4 and 5). This finding was similar to a previous study in which a cereal bar product was made with micronized lentils, where bars with oats replaced with lentils had a higher intensity in “lentil flavor” (Ryland et al., 2010). At a selected level of lentil, pre-roasting the lentil flour for 5 or 10 minutes did not alter the intensities in the Beany aroma and aroma-by-mouth of the crackers (Tables 4 and 5). The 10R100L cracker was significantly more bitter than the other six crackers (Table 5 and Figure 2) which can be caused by the longer pre-roasting treatment of the lentil flour to decrease the lentils’ mealy flavor and increase in burnt flavor (Lazou et al., 2011).

Furthermore, the three samples made of 100% lentil had the highest intensities in Saturated orange and Cheesy aroma and aroma-by-mouth. Although the crackers did not contain cheese or dairy ingredients, the carotenoids in the red lentil that resulted in the Saturated orange color could affect the panelists’ overall perception of the cracker, since color indicates flavor in the consumers’ core perception (Sliburyte and Skertye, 2014). Similarly, in a study involving the color perception of wine, white wine dyed red received many of the olfactory descriptors generally used for red wine (Morot, 2001). Although the panelists were trained and asked to define each term to an autonomous agreement, still may have their own perceptions of each attribute from life experiences. In many cases, consumers are often not only trained for specific panels but are trained in life for descriptive analysis for sensory attributes in food due to the experiences with eating similar products and relating those products back to the test products (Booth, Mobini &

Wainwright, 2003). Thus, the orange appearance of the 100% lentil crackers may have reminded the panelists of commercial cheese crackers which led to the perception of Cheesy.

The intensities in Puffy and Thick visual attributes were the highest in the control sample, followed by the group with 50% lentil (Tables 4 and 5). This may be explained by the fact that the water holding capacity of pulse flours is significantly higher than wheat (Millar et al., 2017), thus more water was released from the wheat containing flours, which created more steam resulting in the puffier and thicker cracker. The presence of gluten might also help to retain the vapor during the baking and resulted in the larger air cells of the baked crackers responsible for the Puffy and Thick attributes. The Control cracker and the crackers with 50% lentil also had higher intensities in Floury aroma, aroma-by-mouth, and aftertaste, and in Saltiney aroma-by-mouth compared to the crackers with 100% lentil (Tables 4 and 5). This is expected due to the higher wheat flour content.

Texture

Texturally, the crackers with 100% lentil presented the highest intensity in Snappy (Figure 2 and Table 6) which may be related to the higher protein and fiber content in lentil flour (Millar et al., 2017), leading to higher hardness of the crackers compared to the crackers with lower levels of lentil, as discussed in the instrumental texture properties (Section 3.1). The 10R100L cracker had the lowest intensity in Easy-to-Dissolve, and a higher intensity in Gritty than most of other samples (Table 6), which could be resulted from the combination of the higher protein and fiber contents and the heat of pre-roasting that led to aggregated protein/fiber/starch particulate structure in the cracker. For the crackers with 50% lentil, increasing in the pre-roasting time of the lentil flour from 0 to 5 and 10 minutes increased the intensities in Crunchy and Gritty texture attributes and decreased the intensity in Flaky attribute (Figure 2 and Table 6). This change may be related to how an increased temperature of lentil flour during the pre-roasting treatment can lower the moisture content and create a crunchier and crisper product (Lazou et al., 2011; Tunick et al, 2013).

Correlations Between the Texture Properties from Instrumental and Sensory Analysis

Figure 3 displays the PCA biplot of the lentil-enriched crackers in the dimensions of instrumental texture and descriptive sensory texture. Agglomerative hierarchical clustering identified two groups based on the texture properties of the crackers. 100% lentil crackers were situated towards the Snappy texture attributes while control was clustered by the Easy-to-Dissolve attribute. 50% lentil crackers situated in between Snappy and Easy-to-Dissolve. Within each group, increasing in the pre-roasting time of the lentil flour shifted the crackers toward the positive end of Gritty and Crunchy QDA attributes.

The instrumental hardness correlated positively with toughness and stiffness ($P < 0.005$, Table 8), and with the QDA terms of Snappy ($P < 0.01$), Crunchy, and Gritty ($P < 0.05$), and negatively with Easy-to-dissolve and Flaky ($P < 0.05$). Such correlations reflected the effect that increasing the lentil level from 0 to 100% created crackers with greater instrumental hardness, toughness, and stiffness, greater intensities in QDA Snappy, Crunchy, Gritty, and lower intensities in Easy-to-dissolve and Flaky (Sections

3.1 and 3.2.1). Such an effect can also be visualized on the PCA bi-plot in which the increase in lentil level shifted the crackers toward the positive end of hardness.

The instrumental crunchiness did not correlate with any other properties in instrumental texture or QDA texture including the QDA Crunchy. The instrumental crunchiness is based on the roughness of the force-time curve during the cracker compression, while the QDA panelists defined Crunchy as an audible noise during the chewing process. Hence the harder crackers may create louder noise of chewing, leading to higher ratings for Crunchy. This is further supported by the positive correlations between instrumental hardness and QDA Crunchy and Snappy. For the six crackers containing lentils, the instrumental crunchiness made no differentiation (Table 3). By contrast (Table 6), the QDA Crunchy differentiated many of the crackers by the level of lentils (0R50L vs. 0R100L, 10R50L vs. 10R100L) and by the pre-roasting time (0R50L vs 5R50L and 10R50L). Such differentiations can be visualized on the PCA biplot, in which increasing in lentil level from 50 to 100% or increasing the lentil flour pre-roasting time shifted the crackers toward the positive end of Crunchy (Figure 3).

The QDA Crunchy correlated positively with Gritty and negatively with Flaky 9 ($P < 0.005$), created by the panelists to describe the mouthfeel of the crackers during chewing (Table 2). As the instrumental texture evaluated the crackers based on force-deformation relationships, QDA offered an expansion of the texture profile by adding mouthfeel during the dynamic chewing process.

Overall consumer sensory acceptance of the lentil-enriched crackers

Without Labeling

The research preceding the present study indicated that, without any labeling, increasing the pre-roasting time of the lentil flour from 5 to 10 minutes did not change the consumers' overall sensory acceptance of the lentil-enriched crackers (Turker et al. *in preparation*). Since increasing in the pre-roasting time of the lentil flour from 5 to 10 minutes presented larger degrees of textural changes from the QDA results (Section 3.2.1) which may help to explore any sensory-labeling interaction of the crackers, the 10-minute pre-roasted lentil flour was used to make the crackers for the consumer acceptance test in this study.

The consumer sensory acceptance test revealed that without labeling effects (Table 9), Control (100% wheat) was the lowest rated sample. This may be related to the Floury and Saltiney attributes and the lack of Saturated Orange visual of the Control cracker observed in the QDA (Tables 4 and 5) that can be perceived as bland and flavorless. Increasing the lentil level from 0 to 50% (0R50L and 10R50L) significantly improved the acceptance rating of the cracker (Table 9). This may be resulting from the enrichment in the cracker color and flavor, as the crackers with 50% lentils presented moderate intensities in Saturated Orange, Roasted legumey, Cheesy, and Umami from the QDA results (Tables 4 and 5). However, at a given pre-roasting time, increasing the lentil level from 50-100% reduced the consumers' acceptance of the crackers (Table 9) which may be due to the overpowering Beany and Bitter attributes observed in the QDA (Tables 4 and 5). At a given lentil level, increasing the pre-roasting time from 0 to 10 minutes did not change the consumers' acceptance of the crackers (Table 9), which can be related to the lack of impact of pre-roasting on the flavor attributes from the QDA results (Tables 4 and 5).

With Different Labeling

There was no significant difference between the different labeling effects (Table 9). The lack of the effectiveness of the "Made in Montana Label" in this study may be partially due to the interactions between the consumers' knowledge of Montana crop specialty and their sensory perceptions of the lentil-enriched crackers. The agglomerative hierarchical clustering of the QDA data showed that 10R50L and Control shared the closest descriptive sensory profile. Both samples have one of the highest intensities in the Saltiney aroma-by-mouth amongst the samples (Table 5). The lower rating of 10R50L labeled with "Made in Montana" compared to the "Low Carbon Footprint" (Table 9) maybe a result of a taste expectation related to Montana wheat products. Montana is known for wheat production, export and overall high quality wheat (Madlom, 2015), and so a product that bears wheat taste and specifically labeled as "Made in Montana" may be subjected to a higher quality standard when evaluated by the consumers, thus, leading to lowered rating. In addition, Smithers et al. (2008) suggested that farmers market shoppers often shop their local farmer's markets in a belief that a social good was being performed also because they like the personal interaction with the venders to share support, trust, and friendliness. Hence, simply labeling a product as local and placing it on a grocery store shelf may not be nearly as appealing as buying a local product directly from the producer. This may explain the overall lack of the effectiveness of the locally made label in this study.

The lack of effectiveness of the “Low Carbon Footprint” label in this study may be due to the fact that environmental benefits in products are often impersonal and delayed, since it has been hypothesized that consumers will only pay a premium if the environmental benefits are connected to their own benefits, therefore health-related are more effective in legume products (Lemken et al., 2017). Also, consumers can be confused (IFIC, 2017) since there are very few products on the market with environmental sustainability claims for them to compare and make a fair judgement (Lemken et al., 2017). The research preceding the present study revealed that the “USDA Organic” label significantly improved consumers’ sensory acceptance of lentil-enriched crackers (Turker et al., *in preparation*), possibly because consumers have known this label well and that organic foods have been associated with not only environmental but also nutritional benefits (IFIC, 2017).

Tables and Figures

Table 3. The Instrumental Texture Properties of the Lentil-enriched Crackers[a].

Sample	Toughness ± SD (kg.s)	Hardness ± SD (kg)	Stiffness ± SD (g/s)	Crunchiness ± SD (%)
Control	117.6 ± 16.9d	31.04 ± 5.82cd	3686.2 ± 575.7d	1.29 ± 0.13b
0R50L	112.0 ± 10.4d	27.42 ± 3.19e	4382.6 ± 752.9cd	1.48 ± 0.18a
0R100L	166.7 ± 11.9b	45.38 ± 4.69a	8648.9 ± 803.6a	1.47 ± 0.16a
5R50L	129.8 ± 22.3c	33.45 ± 4.55c	5274.2 ± 1043.4b	1.41 ± 0.20ab
5R100L	171.7 ± 11.4a	47.24 ± 6.94a	8652.9 ± 920.5a	1.36 ± 0.10ab
10R50L	112.1 ± 15.2d	27.73 ± 4.98de	3903.4 ± 757.8cd	1.44 ± 0.20a
10R100L	177.3 ± 9.9a	40.48 ± 7.57b	4420.2 ± 659.8c	1.52 ± 0.11a

[a] Determined by Fischer's least significant difference (LSD; *a* = 0.05) the values within the same column followed by the same lowercase letters are not significantly different.

Table 4. The Aroma and Visual Properties of Lentil-enriched Crackers Collected via Quantitative Descriptive Analysis (QDA)[a]

Sample[b]	Visual			Aroma			
	Saturated orange ± SD	Puffy ± SD	Thick ± SD	Floury ± SD	Beany ± SD	Roasted legumey ± SD	Cheesy ± SD
Control	1.0 ± 0.0d	14.7 ± 0.6a	14.4 ± 1.4a	15.0 ± 0.0a	1.0 ± 0.0c	1.0 ± 0.0c	1.0 ± 0.0c
0R50L	7.4 ± 2.4c	9.8 ± 1.3c	11.5 ± 0.5b	8.9 ± 2.2b	6.7 ± 2.4b	6.9 ± 2.4b	7.3 ± 2.3b
0R100L	12.6 ± 1.3b	3.0 ± 1.9d	5.6 ± 1.3c	4.1 ± 2.5c	12.9 ± 1.2a	12.8 ± 1.0a	11.0 ± 3.2a
5R50L	7.8 ± 1.9c	9.3 ± 1.9c	11.1 ± 1.3b	9.0 ± 1.8b	7.2 ± 1.3b	7.2 ± 1.6b	7.8 ± 1.6b
5R100L	13.4 ± 0.5ab	2.6 ± 0.6d	4.3 ± 2.4c	4.3 ± 2.9c	13.0 ± 1.0a	13.3 ± 0.6a	10.9 ± 3.3a
10R50L	7.1 ± 1.9c	12.0 ± 0.9b	12.6 ± 1.3b	10.3 ± 3.0b	6.3 ± 2.2b	6.2 ± 2.2b	6.7 ± 2.3b
10R100L	14.6 ± 0.7a	3.1 ± 2.1d	4.0 ± 2.3c	2.4 ± 1.6c	13.8 ± 2.0a	14.1 ± 1.3a	11.0 ± 3.6a

[a] Determined by Fischer's least significant difference (LSD; a = 0.05) the values followed by the same lowercase letters are not significantly different within attribute column. The attributes without any significant difference between any samples were not listed.
[b] Samples are coded with lentil pre-roasting treatment by minutes and percentage of lentil flour used for example 0R100L indicates the cracker was made from lentil flour pre-roasted for 0 min (non-roasted lentil flour) with 100 percent lentil flour.

Table 5. The Aroma-by-Mouth, Taste and Aftertaste Properties of Lentil-enriched Crackers Collected via Quantitative Descriptive Analysis (QDA)[a]

Sample[b]	Aroma-by-mouth					Taste		Aftertaste		
	Beany ± SD	Cheesy ± SD	Floury ± SD	Saltiney ± SD	Baked ± SD	Umami ± SD	Bitter ± SD	Umami ± SD	Beany ± SD	Floury ± SD
Control	1.0 ± 0.1c	1.0 ± 0.0d	15.0 ± 0.0a	12.3 ± 5.1a	2.6 ± 2.4d	2.5 ± 4.4c	1.1 ± 0.2d	2.4 ± 4.0c	1.0 ± 0.0c	15.0 ± 0.0a
0R50L	7.1 ± 3.0b	7.0 ± 3.2c	10.3 ± 1.5b	8.7 ± 2.4ab	6.2 ± 1.3c	8.0 ± 2.0b	5.2 ± 2.5c	7.6 ± 2.9b	7.0 ± 2.8b	10.3 ± 1.8b
0R100L	12.8 ± 1.1a	11.4 ± 2.9a	4.6 ± 1.8c	6.2 ± 4.2bc	12.4 ± 1.9b	11.6 ± 2.4a	11.6 ± 2.0b	11.7 ± 2.2a	12.6 ± 1.3a	4.5 ± 2.6a
5R50L	6.9 ± 2.6b	8.2 ± 2.9bc	9.9 ± 1.3b	9.3 ± 1.6ab	6.9 ± 1.3c	7.7 ± 2.5b	5.9 ± 2.0c	8.0 ± 2.2b	6.7 ± 2.3b	8.9 ± 1.9b
5R100L	13.4 ± 1.0a	10.6 ± 3.7ab	4.2 ± 2.8cd	5.7 ± 4.1bc	13.4 ± 0.9ab	12.4 ± 3.1a	12.3 ± 1.5b	12.5 ± 2.6a	13.3 ± 1.2a	4.4 ± 3.0c
10R50L	6.3 ± 2.8b	7.1 ± 2.3c	11.2 ± 2.0b	10.1 ± 2.5a	6.1 ± 1.9c	6.2 ± 2.6b	4.5 ± 2.3c	5.9 ± 2.6b	6.0 ± 2.3b	10.3 ± 2.3b
10R100L	14.0 ± 2.1a	10.4 ± 3.8ab	2.4 ± 1.9d	4.3 ± 4.6c	14.8 ± 0.4a	12.6 ± 4.0a	14.7 ± 0.5a	12.2 ± 4.2a	13.6 ± 2.6a	2.9 ± 2.0c

[a]Determined by Fischer's least significant difference (LSD; *a* = 0.05) the values followed by the same lowercase letters are not significantly different within attribute column. The attributes without any significant difference between any samples were not listed.
[b] Samples are coded with lentil pre-roasting treatment by minutes and percentage of lentil flour used for example 0R100L indicates the cracker was made from lentil flour pre-roasted for 0 min (non-roasted lentil flour) with 100 percent lentil flour.

Table 6. The Texture Properties of Lentil-enriched Crackers Collected via Quantitative Descriptive Analysis (QDA)[a]

Sample[b]	Snappy ± SD	Easy-to-dissolve ± SD	Crunchy ± SD	Gritty ± SD	Flaky ± SD
Control	3.2 ± 2.3c	11.0 ± 3.7a	6.4 ± 0.8c	5.4 ± 1.7c	10.5 ± 1.5b
0R50L	7.9 ± 1.6b	10.6 ± 2.4a	6.0 ± 1.7c	4.4 ± 1.9c	12.3 ± 1.5a
0R100L	13.2 ± 1.7a	8.6 ± 3.2a	10.9 ± 1.6ab	9.6 ± 1.6b	6.7 ± 1.6de
5R50L	7.6 ± 2.0b	10.7 ± 1.3a	10.3 ± 1.5ab	8.7 ± 1.5b	9.4 ± 2.2bc
5R100L	13.5 ± 0.6a	8.5 ± 3.0a	11.1 ± 1.2a	10.3 ± 1.5ab	6.7 ± 2.1de
10R50L	7.3 ± 2.0b	11.0 ± 2.4a	9.5 ± 2.2b	8.7 ± 1.7b	8.4 ± 1.1cd
10R100L	14.7 ± 0.4a	4.4 ± 2.7b	11.5 ± 1.1a	11.3 ± 0.9a	5.8 ± 2.1e

[a] Determined by Fisher's least significant difference (LSD; a = 0.05)test. The values within a column followed by the same lowercase letters are not significantly different. The attributes without any significant difference between any samples were not listed.
[b] Samples are coded with lentil pre-roasting treatment by minutes and percentage of lentil flour used for example 0R100L indicates the cracker was made from lentil flour pre-roasted for 0 min (non-roasted lentil flour) with 100 percent lentil flour.

Table 7. Pearson Correlation Matrix Between the Attributes Obtained from Quantitative Descriptive Analysis (QDA)[ab].

Variables		Visual			Aroma				Aroma by mouth (ABM)					Taste (T)		After taste (AT)			Texture				
		S. O.	Puffy	Thick	Floury	Beany	R.L.	Cheesy	Beany	Cheesy	Floury	Saltiney	Baked	Umami	Bitter	Umami	Beany	Floury	Snappy	E.T.D	Crunchy	Gritty	Flaky
Visu	S. O.	**1**																					
	Puffy	**-0.96**	**1**																				
	Thick	**-0.96**	**0.99**	**1**																			
Aroma	Floury	**-1.00**	**0.97**	**0.96**	**1**																		
	Beany	**1.00**	**-0.99**	**-0.97**	**-0.99**	**1**																	
	R. L.	**1.00**	**-0.98**	**-0.98**	**-1.00**	**1.00**	**1**																
	Cheesy	**0.98**	**-0.94**	**-0.90**	**-0.97**	**0.98**	**0.97**	**1**															
ABM	Beany	**1.00**	**-0.98**	**-0.97**	**-0.99**	**1.00**	**1.00**	**0.97**	**1**														
	Cheesy	**0.96**	**-0.92**	**-0.87**	**-0.95**	**0.96**	**0.95**	**0.99**	**0.95**	**1**													
	Floury	**-0.99**	**0.98**	**0.99**	**0.99**	**-0.99**	**-1.00**	**-0.95**	**-0.99**	**-0.92**	**1**												
	Saltiney	**-0.98**	**0.97**	**0.97**	**0.99**	**-0.98**	**-0.98**	**-0.94**	**-0.98**	**-0.90**	**0.99**	**1**											
	Baked	**0.98**	**-0.98**	**-1.00**	**-0.98**	**0.99**	**0.99**	**0.93**	**0.99**	**0.90**	**-1.00**	**-0.98**	**1**										
T	Umami	**0.99**	**-0.99**	**-0.97**	**-0.99**	**0.99**	**0.99**	**0.98**	**0.99**	**0.95**	**-0.99**	**-0.99**	**0.97**	**1**									
	Bitter	**0.98**	**-0.99**	**-0.99**	**-0.98**	**0.98**	**0.99**	**0.92**	**0.98**	**0.89**	**-1.00**	**-0.99**	**1.00**	**0.97**	**1**								
AT	Umami	**0.98**	**-0.99**	**-0.97**	**-0.99**	**0.99**	**0.99**	**0.98**	**0.99**	**0.95**	**-0.98**	**-0.97**	**0.97**	**1.00**	**0.97**	**1**							
	Beany	**0.99**	**-0.99**	**-0.98**	**-0.99**	**1.00**	**1.00**	**0.97**	**1.00**	**0.95**	**-0.99**	**-0.98**	**0.99**	**1.00**	**0.98**	**0.99**	**1**						
	Floury	**-1.00**	**0.98**	**0.97**	**0.99**	**-1.00**	**-1.00**	**-0.97**	**-0.99**	**-0.95**	**0.99**	**0.98**	**-0.99**	**-0.99**	**-0.99**	**-0.98**	**-0.99**	**1**					
Texture	Snappy	**0.99**	**-0.98**	**-0.98**	**-0.99**	**1.00**	**1.00**	**0.95**	**1.00**	**0.93**	**-1.00**	**-0.99**	**0.99**	**0.99**	**0.99**	**0.98**	**1.00**	**-0.99**	**1**				
	E.T.D.	**-0.80**	**0.77**	**0.84**	**0.81**	**-0.79**	**-0.80**	-0.67	**-0.79**	-0.61	**0.85**	**0.87**	**-0.86**	**-0.77**	**-0.88**	-0.75	**-0.78**	**0.81**	**-0.83**	**1**			
	Crunchy	**0.81**	**-0.77**	**-0.78**	**-0.78**	**0.82**	**0.81**	**0.79**	**0.80**	**0.81**	**-0.80**	-0.74	**0.82**	**0.76**	**0.81**	**0.78**	**0.79**	**-0.85**	**0.79**	-0.64	**1**		
	Gritty	**0.80**	-0.75	**-0.79**	**-0.77**	**0.80**	**0.80**	0.75	**0.78**	0.75	**-0.80**	-0.74	**0.83**	0.74	**0.82**	0.75	**0.77**	**-0.83**	**0.79**	-0.71	**0.99**	**1**	
	Flaky	**-0.79**	**0.77**	**0.82**	**0.76**	**-0.80**	**-0.80**	-0.70	**-0.79**	-0.70	**0.81**	0.75	**-0.85**	-0.73	**-0.83**	-0.74	**-0.78**	**0.82**	**-0.81**	0.75	**-0.93**	**-0.96**	**1**

a The coefficient in bold font indicates a significant correlation determined by Pearson correlation test (*a* = 0.05).
b S.O, R.L, and E.T.D refers to saturated orange, roasted legumey, and easy-to-dissolve, respectively.

Table 8. Pearson Correlation Matrix Between the Properties Obtained from the Instrumental Texture Analysis and Quantitative Descriptive Analysis (QDA)[a].

Variables		Instrumental Texture			QDA -Texture				
		Toughness	Hardness	Stiffness	Snappy	Easy-to-dissolve	Crunchy	Gritty	Flaky
Instrumental Texture	Toughness	1							
	Hardness	0.99***	1						
	Stiffness	0.97***	0.98***	1					
QDA -Texture	Snappy	0.87*	0.88**	0.95***	1				
	Easy-to-dissolve	-0.68	-0.76*	-0.79*	-0.82*	1			
	Crunchy	0.78*	0.79*	0.79*	0.79*	-0.64	1		
	Gritty	0.76*	0.79*	0.78*	0.79*	-0.71	0.99***	1	
	Flaky	-0.82*	-0.86*	-0.83**	-0.81*	0.75	-0.93***	-0.96***	1

[a] The coefficient followed by *, **, and *** indicates a significant correlation determined by Pearson correlation test at *a* = 0.005, 0.01, and 0.05 respectively. Properties without any significant correlation with any other properties are excluded from the table.

Table 9. Effect of Labeling on the Consumer Sensory Acceptance of the Lentil-enriched Crackers[a].

	Mean ± SD		
Sample[b]	**No label**	**Made in Montana**	**Low carbon footprint**
Control	4.5 ± 2.1d,A	4.2 ± 2.1c,A	4.4 ± 2.0c,A
0R50L	5.8 ± 2.0a,A	5.8 ± 1.7a,A	5.7 ± 2.0a,A
0R100L	5.2 ± 2.1bc,A	5.1 ± 2.1b,A	5.3 ± 2.0ab,A
10R50L	5.6 ± 1.6ab,AB	5.1 ± 1.7b,B	5.6 ± 1.6a,A
10R100L	4.8 ± 1.9cd, A	4.7 ± 1.8bc,A	5.0 ± 2.0 b,A

[a] Fisher's least significant difference (LSD; $a = 0.05$) test was performed. The values in a column followed by the same lowercase letters are not significantly different. For labeling effect on each sample the values within a row followed by the same uppercase letters are not significantly different.
[b] Refer to Table 1 for sample coding, formulation, and preparation

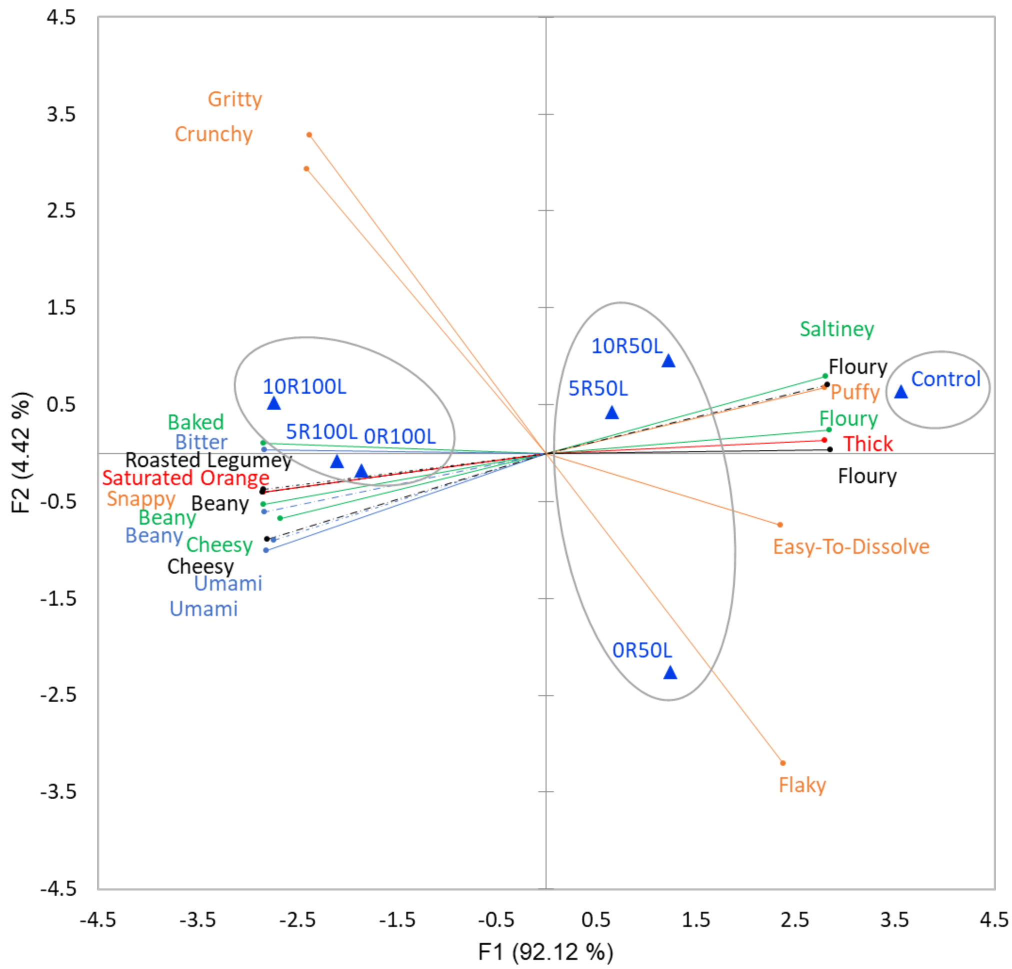

Figure 2– Principal Component Biplot by F1 and F2 of Significant QDA Terms of the Lentil-enriched Crackers. Sample code: lentil flour pre-roasting treatment (0-10min), lentil ratio (% w/w). Color coded for each modality: aroma, black dashed line; aroma-by-mouth (ABM), green solid line; taste, blue solid line; aftertaste, blue dashed line, visual, red solid line; texture, yellow solid line. The grey circles indicate the grouping of the samples based on the agglomerative hierarchical clustering.

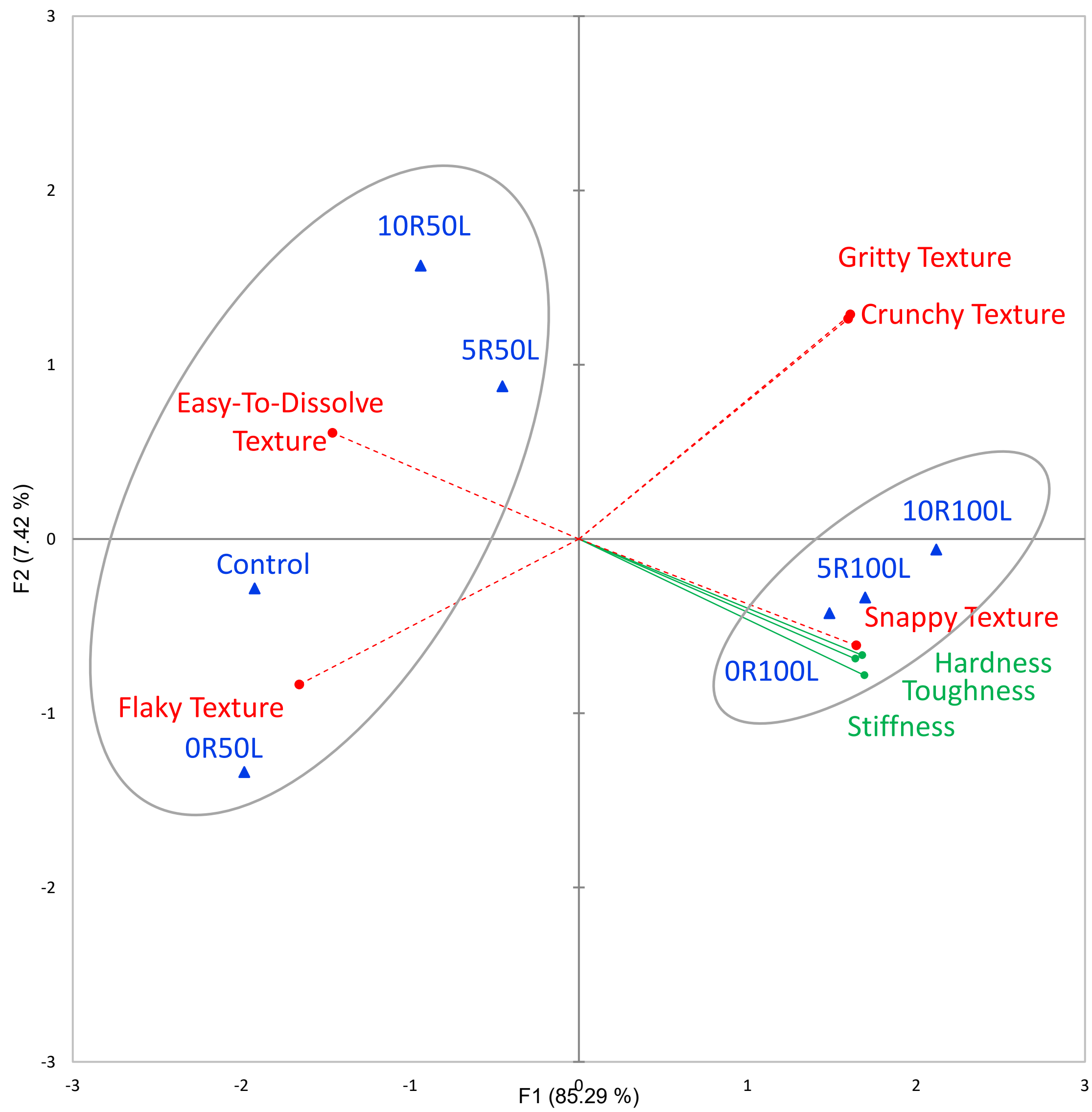

Figure 3 – Principal Component Biplot by F1 and F2 of the Significant QDA Texture Terms and Instrumental Texture Measurements. Sample code: lentil flour pre-roasting treatment (0-10min), lentil ratio (% w/w). Color code for each variable: QDA Texture, red dashed line; instrumental texture, green solid line. The grey circles indicate the grouping of the samples based on the agglomerative hierarchical clustering

CONCLUSION

In this study, increased lentil level in the crackers resulted in a tougher, stiffer and harder cracker. Pre-roasting lentil flour for 10-minutes significantly reduced hardness and stiffness of the crackers. Crackers that contained non-roasted lentil flour or 10-minute pre-roasted lentil flour were crunchier than the control cracker. QDA revealed that 100% lentil crackers (0R100L, 5R100L and 10R100L) shared sensorial attributes of Saturated Orange visual being positively correlated to a series of terms in aroma, aroma-by-mouth, taste and after taste in Beany, Roasted Legumey, Cheesy, Baked, Umami and Bitter. 100% lentil crackers also showed significantly higher intensities in Beany aroma-by-mouth and 10R100L was significantly more Bitter in taste than the other six crackers. Control crackers were described by Puffy and Thick visual, Saltiney aroma-by-mouth, and Floury aroma, aroma-by-mouth and aftertaste. 50% lentil crackers (0R50L, 5R50L and 10R50L) shared attributes between 100% lentil crackers and the control. QDA also revealed 100% lentil crackers presented the highest intensity in Snappy texture and 10R100L had the lowest intensity in Easy-to-Dissolve texture and highest intensity in Gritty texture. For 50% lentil crackers, increasing pre-roasting time of lentil flour from 0 to 5 and 10 increased intensity in Crunchy and Gritty texture and decreased intensity in Flaky texture. Furthermore, instrumental hardness correlated ($P<0.005$) positively with toughness and stiffness, and QDA texture terms Snappy ($P<0.01$), Crunchy ($P<0.05$), and Gritty ($P<0.05$). Instrumental hardness negatively correlated ($P<0.005$) with QDA texture terms Easy-to-dissolve and Flaky ($P<0.05$). Instrumental crunchiness did not correlate with any other instrumental texture or QDA texture terms. Sensory analysis revealed that with no-labeling effect, control was the lowest rated sample and the 0R50L and 10R50L had a significantly higher acceptance rating. Labeling effect did not show significant different between crackers. Therefore, consumers may need to be more educated on low carbon footprint and Made in Montana labeling and products for it to make.

This study's utilization of texture and sensory analysis techniques can help further build the knowledge and expertise to future lentil product development and product labeling. Future works of this research can help better understand effect of packaging, shelf-life and marketing on creating a local commercial value-added product and can support Montana producers to help stimulate the local food system and local Montana economy.

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