NYWGF RESEARCH - FINAL REPORT

Funding for fiscal year: 2024-2025

SECTION 1:

Project title: Development of High-Fiber, Protein-Rich Snacks from Whole Concord Grapes

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New Research ☒ **Continued Research** ☐

Amount Funded **$** 18,269

SECTION 2:

Project Summary Impact Statement: Current Concord grape products mainly include juice, jam and jelly. This project aimed at developing high-fiber, protein rich snacks from whole Concord grapes and sustainable protein sources, which follows the modern diet habits, and provide consumers with a new, healthy, delicious, and nutritious option of eating Concord grapes. Liquid shakes and dried snack bars were formulated, then manufactured into delicious, shelf-stable products using advanced thermal and nonthermal technologies. The quality attributes and processing parameters were determined and optimized. The new snack products were protein- and fiber-rich, nutritionally balanced, had good sensory properties, and had desired shelf life, thus the project is considered successful. With the dissemination of the new products through the team's extension program, the consumption of Concord grapes would likely be enhanced and therefore, increase their demand for production.

Objectives: This project aims to enhance the consumption of Concord grapes in the New York State by developing novel high-fiber, protein-rich whole-food snacks, aligning with the New York Wine and Grape Foundation's (NYWGF) and NY Department of Agriculture and Market's joint goal to promote the Concord grape industry in the state. To achieve this goal, this project will focus on two specific objectives: 1) Develop suitable formulation of the snacks and characterize their attributes; 2) Investigate and determine the suitable processing and preservation methods to produce shelf-stable products.

Materials & Methods:
Objective 1: Develop suitable formulation of the snacks and characterize their attributes (conduct in the Postharvest Technologies Lab and Food Processing Lab at Cornell AgriTech in Geneva, NY)

Task 1.1: sample preparation and pretreatment:
Whole hemp seeds, whole red beans, as well as whey proteins will be obtained from local suppliers, Concord grapes will be harvested in local vineyards. Various pretreatment methods for the raw materials will be studied, which could include but not limited to cleaning, water soaking, milling and cooking of red bean and hemp seeds, de-seeding of the grapes.

Task 1.2: formulation and characterization:
Two target products will be studied: pouched smoothie and dried snack bars. The percentage of the whole Concord grape, protein source (whole hemp seed, whole red bean, or whey powder), and other ingredients (including but not limited to water, salt, starch, grains or tree nuts) will be determined. The important product attributes of the formulated products will be characterized, which include but not limited to pH, acidity, particle size, viscosity, color, moisture content, water activity, and nutritional properties (contents of carbohydrate, protein, lipid, dietary fiber, and minerals). The most suitable formulations for each type of product will be determined and used in Objective 2 for studying the processing and preservation performances.

Objective 2: Investigate and determine suitable processing and preservation methods to produce shelf-stable products (conduct in the Cornell Food Venture Center and Cornell Food Innovation Lab at Cornell AgriTech in Geneva, NY).
Task 2.1: thermal preservation of pouched protein-rich liquid shake:
The flow diagram describing the formulation and processing steps of the liquid shake products is shown in Figure 1. The formulated material will be homogenized using a food processor (R302V, Robot Coupe USA. Inc., Ridgeland, MS, USA). The homogenate will then be further pureed using a Ross high shear mixer (HSM-100LSK-I, Charles Ross & Son Company, Hauppauge, NY, USA). The puree will be hand-filled into food-grade pouches and thermally sealed. The pouches will be pasteurized in a vertical autoclave (Terra Food-Tech, Spain) at different temperatures and durations. The important quality attributes of the pasteurized smoothie will be determined.

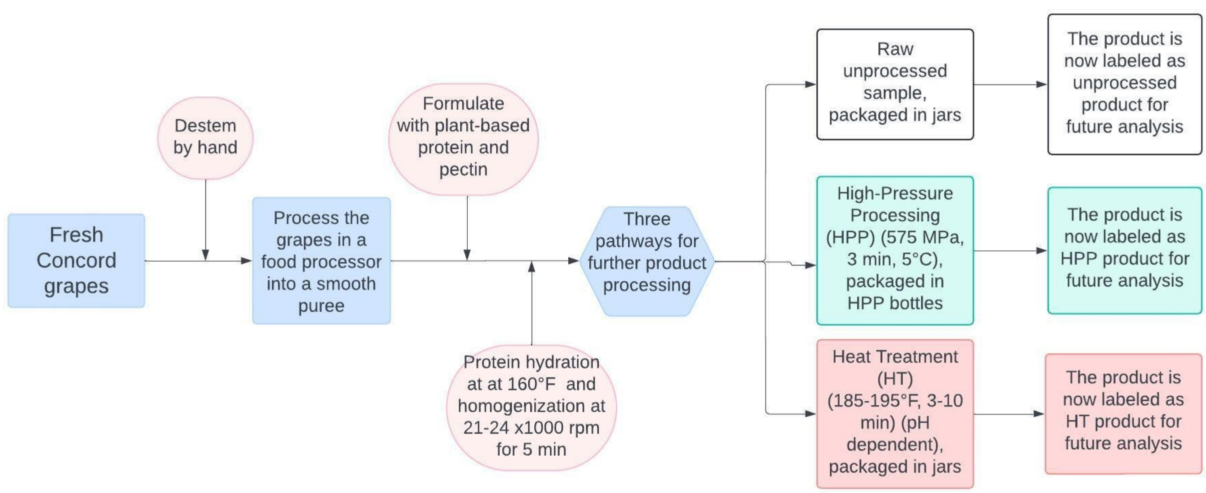


Figure 1. Flow diagram to produce whole Concord grape puree and the formulated protein enriched products.

Task 2.2: production of dried protein-fruit bars

The flow diagram describing the formulation and processing steps of the dried snack bar products is shown in Figure 2. The formulated material will be weighed and shaped into bars and processed using freeze drying or microwave vacuum drying. For freeze drying, a pilot-scale freeze dryer (Harvest Right, Salt Lake City, UT, USA) will be used. Different shelving temperature and vacuum pressure will be tested. The microwave vacuum drying will be performed in a pilot-scale 10 kW EnWave microwave vacuum dryer (EnWave, BC, Canada). The influence of the various processing conditions (power input, vacuum pressure, heating time and durations) on drying time and quality attributes will be investigated.

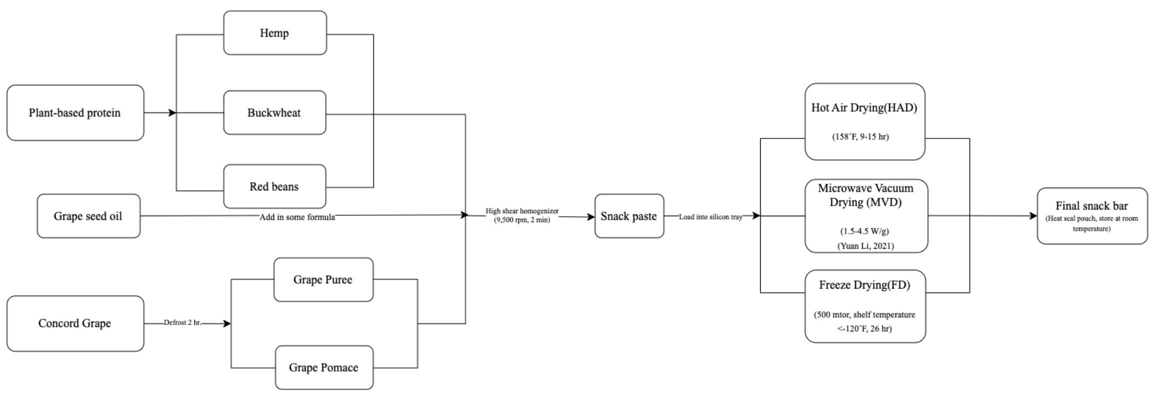


Figure 2. Process diagram showing how the snack bars are made.

Results/Outcomes/Next Steps:

Liquid protein-rich shake

Controlling pH is one of the most important parts in product development, especially in the food industry, for ensuring the quality, safety, and stability of the final product. pH control plays a significant role in maintaining the desired physicochemical properties during production. The influence of enriching the whole Concord grape puree with 2%-10% chickpea protein, pea protein, and mung bean protein on the pH of the products are shown in Figure 3. Pea protein and chickpea protein showed promising results and was selected, and up to 8% protein addition maintained the product pH below 4.3 that is needed for the safety of the product.

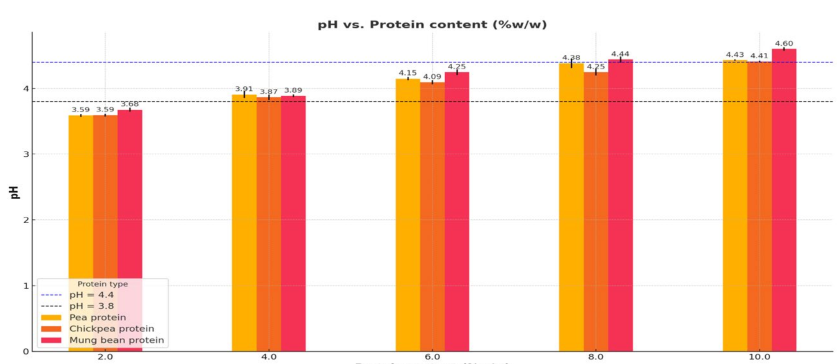


Figure 3. pH of Concord grape puree enriched with chickpea protein, pea protein, and mung

bean protein (2 to 10% ww).

Color and visual appearance are primary factors that influence consumer perception and acceptance. Anthocyanins, which are water-soluble pigments found in grape skin cells, are responsible for the distinctive red, purple, or dark blue colors of Concord and other red grape varieties. The influence of HPP and thermal pasteurization (HT), can significantly impact the stability of these pigments and, consequently, the overall quality of the grape puree. As shown in Figure 4 and Figure 5, pea protein products showed better color retention than the chickpea protein products, and up to 8% protein enrichment did not show significant color change. HPP treated shakes exhibited more noticeable color changes than the HT. The color metrics (8% protein addition) for both products are summarized in Table 1.

Figure 4. Color of liquid shake product enriched with pea protein (From left to right 4%, 6%, 8% pea protein formulation; containers left to right: unprocessed, HT, HPP)

Figure 5. Color of liquid shake product enriched with chickpea protein (From left to right 4%, 6%, 8% chickpea protein formulation; containers left to right: unprocessed, HT, HPP)

Table 1. Color of whole Concord grape puree with 8% pea and chickpea protein added.

Protein	Treatment	Lightness (L*)	Red/Green (a*)	Yellow/Blue (b*)	Color Difference (ΔE)
Pea protein	Raw	38.9 ± 1.7 a	4.4 ± 0.2 a	-1.7 ± 0.2 a	-
	HT	39.8 ± 1.2 a	3.6 ± 0.2 a	-1.2 ± 0.2 a	1.4 ± 0.9 a
	HPP	37.1 ± 2.2 a	3.7 ± 0.7 a	-2.2 ± 0.2 a	2.9 ± 0.9 a

Chickpea protein	Raw	41.1 ± 2.1 a	3.9 ± 1.6 a	2.1 ± 0.3 ab	-
	HT	39.5 ± 3.1 a	3.6 ± 0.9 a	3.1 ± 0.4 a	2.0 ± 0.7 a
	HPP	39.7 ± 1.6 a	4.2 ± 0.8 a	1.6 ± 0.2 b	2.5 ± 0.5 a

Values presented are mean ± standard deviation (n=3). Values with different letters in each column are significantly different (ANOVA, Tukey's HSD, $p<0.05$).

The influence of the protein addition and processing on the anthocyanin retention in the products was evaluated by measuring the total monomeric anthocyanin content (TMA), as shown in Figure 6 and 7. At 4% and 6% protein concentration, for both pea protein and chickpea protein enriched products, neither TMA changes were significantly different after HT nor HPP processing, while significant differences were found at 8% protein concentration for both formulations. HT displayed a better TMA retention over HPP when pea protein was involved, HPP kept more TMA over HT when chickpea protein was used to enrich whole Concord grape puree.

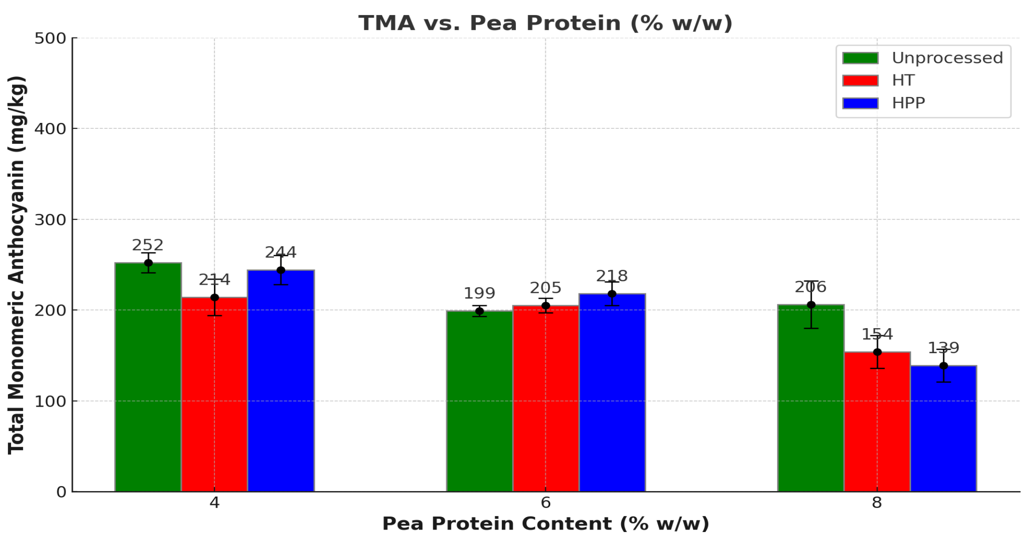


Figure 6. Comparison of Total Monomeric Anthocyanin Content (TMA) of whole Concord grape puree with pea protein added.

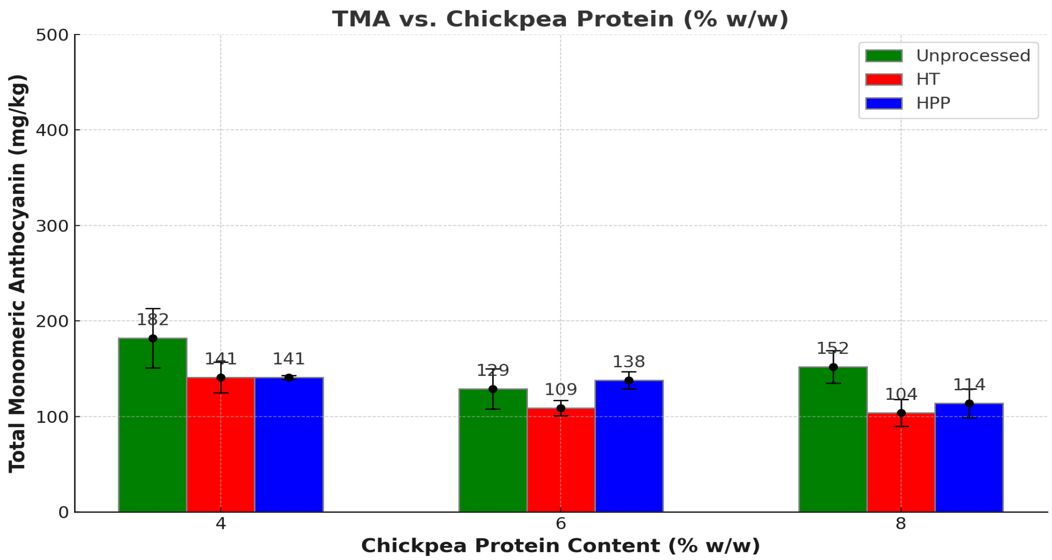


Figure 7. Comparison of Total Monomeric Anthocyanin Content (TMA) of whole concord grape puree with chickpea protein added.

The particle size of the sample can significantly influence the product's properties, which are essential for achieving targeted formulations. This aspect is crucial for developing stable and effective products. Moreover, particle size is pivotal in controlling industrial processes, impacting the dissolution properties and bioavailability of the final product. The particle size distribution of the pea protein (PP) and chickpea proteins (CP) enriched samples (8% protein addition) are shown in Figure 8 and 9.

The study examines the impact of unprocessed (raw), heat-treated (HT), and high-pressure processed (HPP) methods on the particle size distributions of these proteins at concentrations of 4%, 6%, and 8%. Notably, the HPP-treated samples consistently exhibited the highest peak volume percentages across all concentrations and particle sizes, indicating that high pressure effectively induces uniform particle breakage and aggregation at specific sizes. In contrast, the HT samples, particularly the 4% CP, showed a significant shift with a pronounced peak around 1000 µm, suggesting substantial particle aggregation likely due to protein denaturation caused by heat. The increase in concentration from 4% to 8% resulted in higher volume percentages at smaller particle sizes for both PP and CP samples, underscoring the role of concentration in enhancing particle interactions and uniformity.

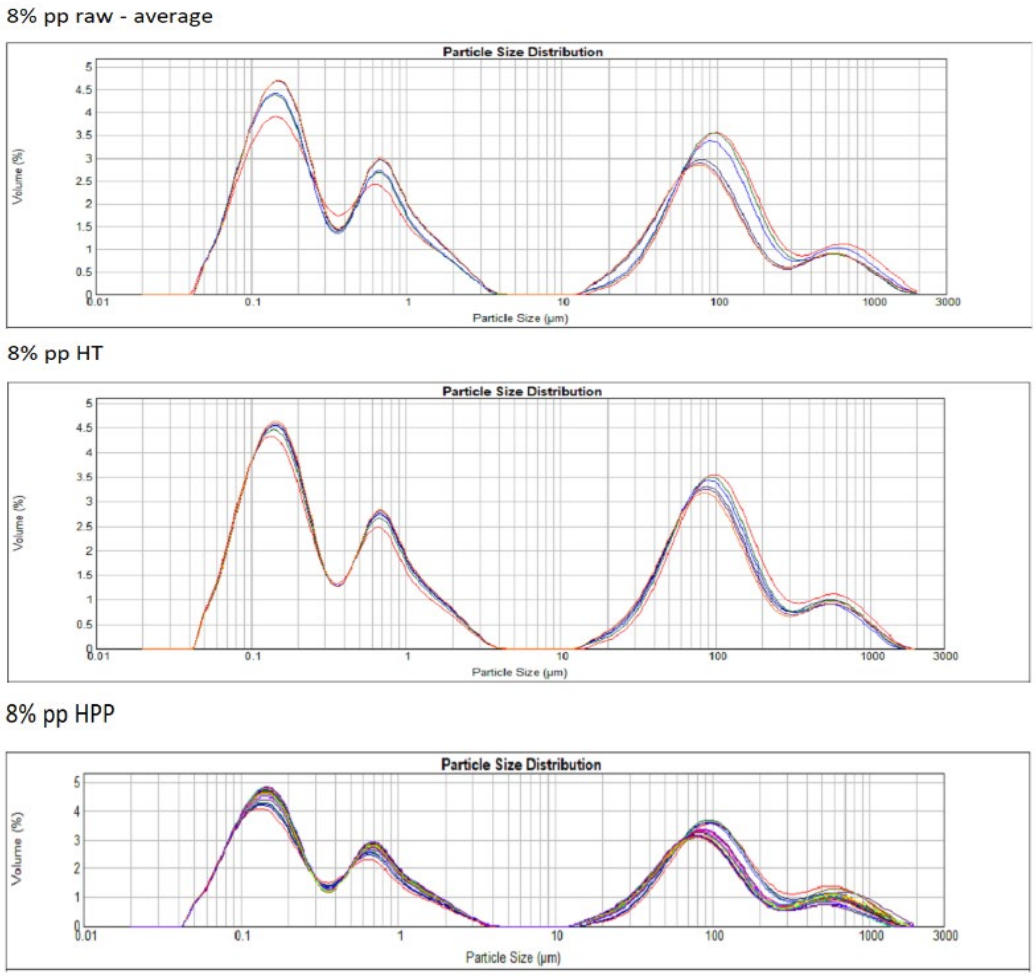


Figure 7. Particle size distribution of whole concord grape puree formulated with pea protein

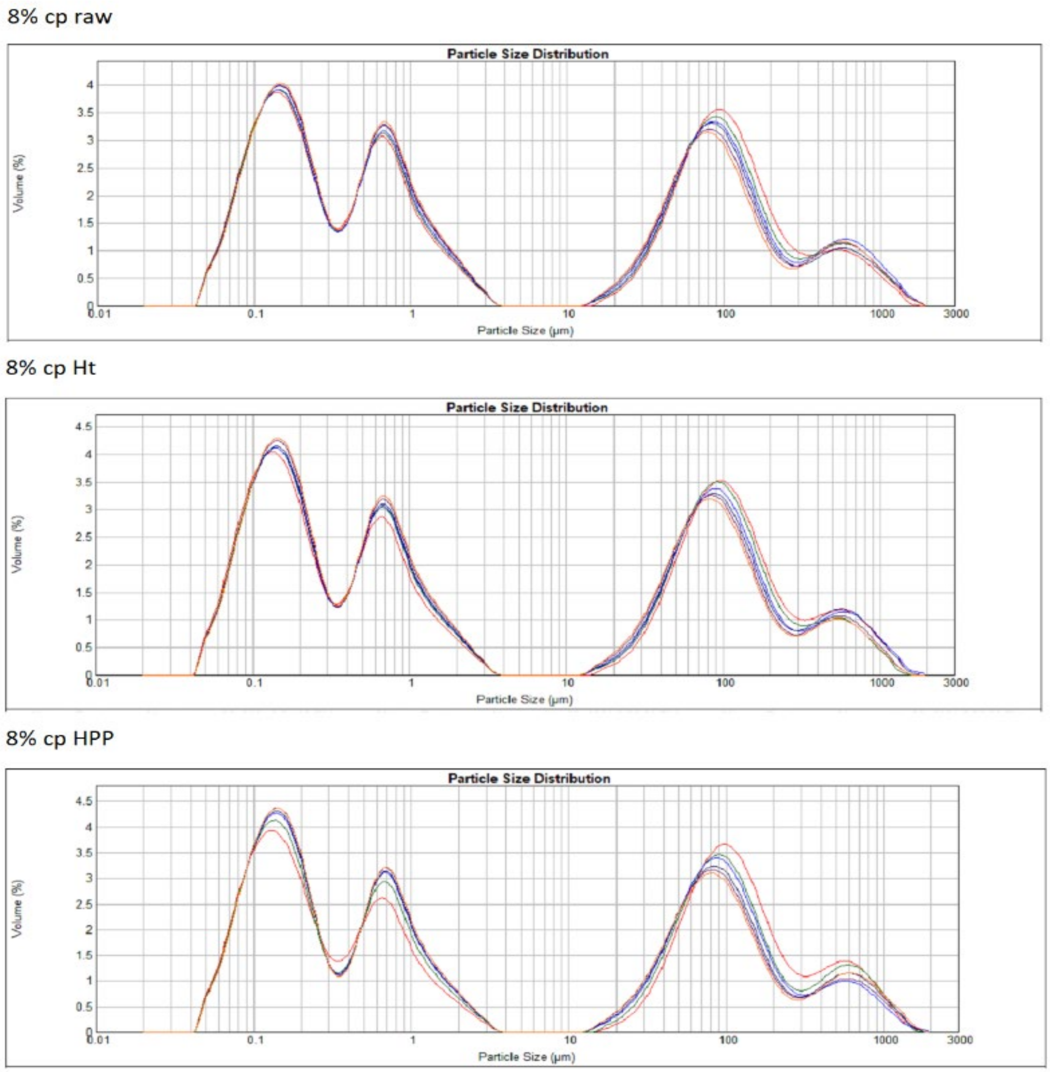


Figure 8. Particle size distribution of whole Concord grape puree formulated with chickpea protein.

The viscosity of the products with different protein concentrations and processing conditions reveals distinct patterns, as shown in Figure 9 and 10. For pea protein products, viscosity increased consistently with higher protein content in unprocessed samples, indicating enhanced protein-protein interactions. Heat treatment further elevated viscosity significantly, particularly at higher concentrations, due to protein denaturation and aggregation, which created a more extensive protein network. High-pressure processing (HPP) also increased viscosity but to a lesser extent than heat treatment, suggesting that while HPP induced protein interactions and some structural changes, it did not cause as extensive aggregation as heat treatment. Chickpea protein products showed more variability in their viscosity response. Unprocessed CP samples had inconsistent viscosity changes with concentration, likely due to the structural differences in chickpea proteins that affected their interaction and aggregation behavior. Heat-treated CP samples exhibited exceptionally high viscosity at lower concentrations, indicative of gel formation, while higher concentrations showed more moderate increases, reflecting the complex nature of CP's response to heat-induced denaturation and aggregation. HPP-treated CP samples demonstrated moderate viscosity increases, implying that HPP effectively enhanced protein interactions without extensive structural disruption.

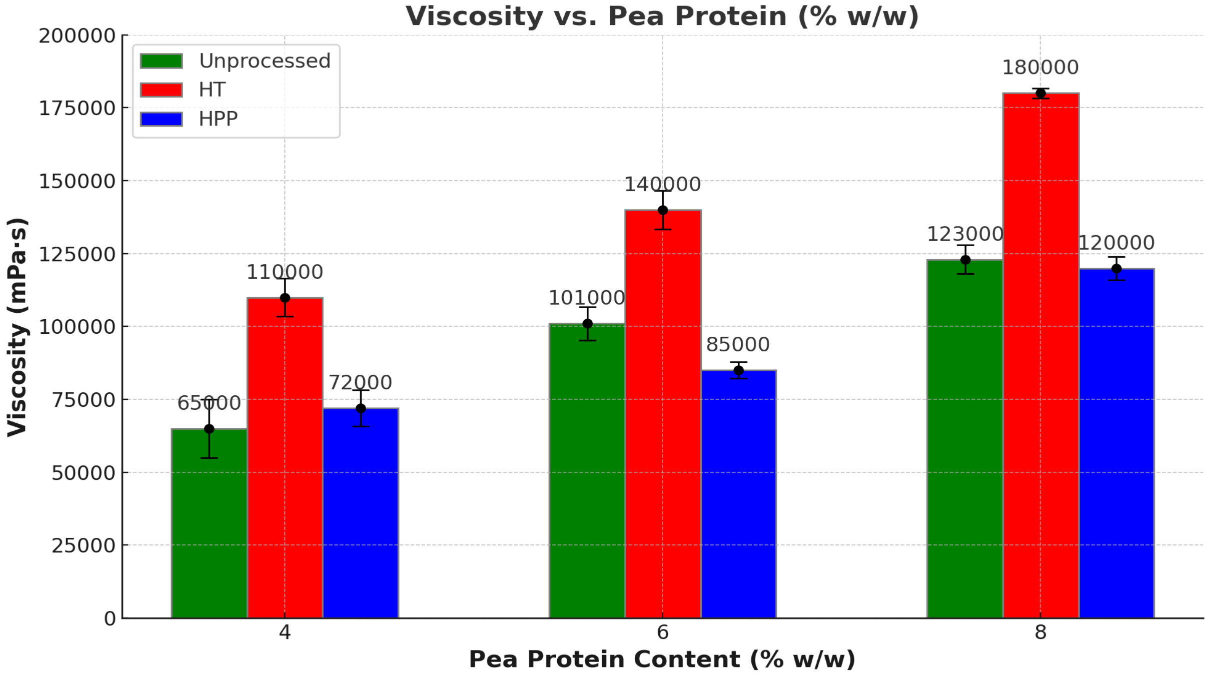


Figure 9. Comparison of processing methods - Viscosity (L-4 spindle at room temperature measuring at 3 rpm for 60 seconds) of whole Concord grape puree formulated with pea protein.

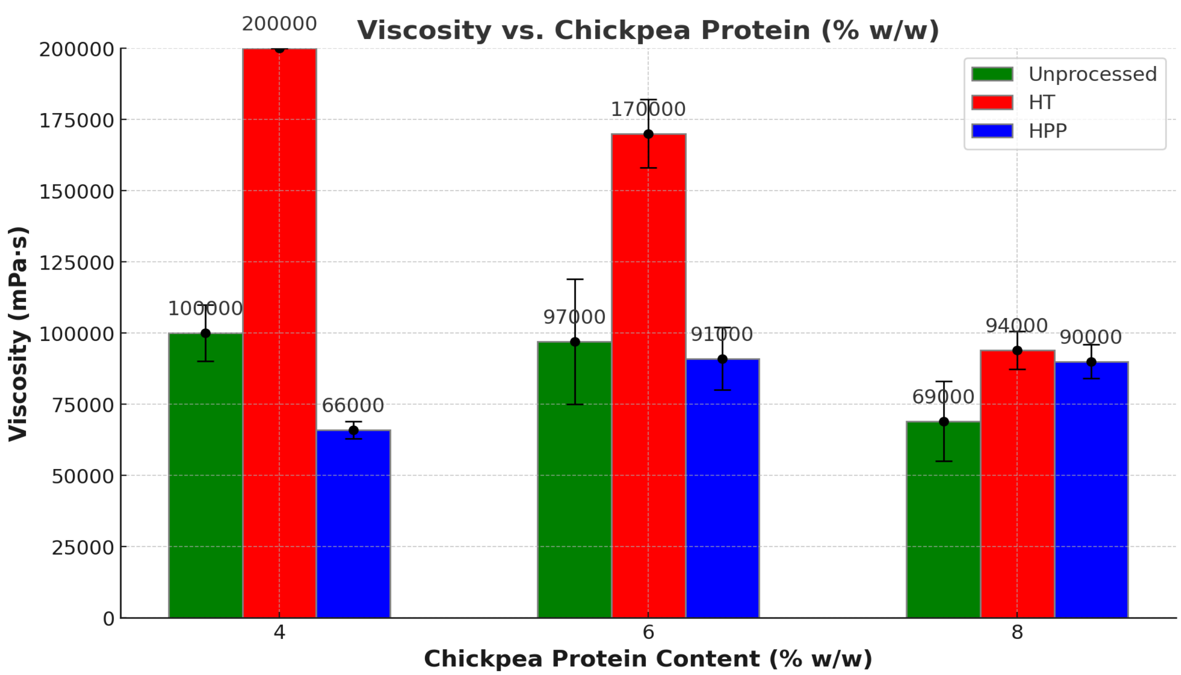


Figure 10. Comparison of processing methods - Viscosity (L-4 spindle at room temperature measuring at 3 rpm for 60 seconds) of whole concord grape puree formulated with chickpea protein

Dried snack bar

Based on the preliminary results, formulations were adjusted as shown in Table 2. Sample of each formulation were prepared and assessed on taste texture, and mouthfeel (informal by lab members). All the mini samples were loaded at 20 g each into the silicone molds. The H30-P (30% w/w of hemp with grape pomace) still needed a binder to hold its structure. It tasted better than R40-P (40% w/w of red beans with grape pomace) with a barely detectible grape flavor. The hemp sample with the pomace needed more moisture. The red beans with pomace tasted too bland and were very starchy. For the overall sensory evaluation of these formulation with whole grape puree, results indicated reasonable acceptance in terms of flavor although some of them were perceived as too dry (R40-WG). The combination of buckwheat with whole grape puree in each formula was acceptable with a tarty grape flavor, while the B20-WG (20% w/w of buckwheat with whole grape) had a little harder texture and was less sour. Both hemp samples had a great puffy texture and not too dry. The higher percentage of hemp in H30-WG made it a little sweeter than H25-WG.

Table 2. The ingredients ratio of all selected formulas (grape pomace & grape puree).

Recipe	Grains (g)	Whole Grape (g)	Pomace (g)	Water for pomace mixture (g)	Total (g)
H30-P	30.00		21.00	49.00	100.00
R40-P	40.00		18.00	42.00	100.00
H25-WG	25.00	75.00			100.00
H30-WG	30.00	70.00			100.00
B15-WG	15.00	85.00			100.00
B20-WG	20.00	80.00			100.00
R30-WG	30.00	70.00			100.00
R40-WG	40.00	60.00			100.00

The influence of the drying methods (freeze drying, hot air drying, microwave vacuum drying) on the appearance of the snack bars are shown in Figure 11, 12 and 13. It was shown that freeze drying resulted in the best color retention, while hot air drying caused significant discoloration and darkening in the products. In comparison, the microwave vacuum dried snack bars had moderate color retention. It was noted that MVD resulted in burning and shattering of the hemp samples, which should be attributed to the non-uniform absorption of microwave radiation in the samples due to the heterogeneity of the hemp seeds in the samples.

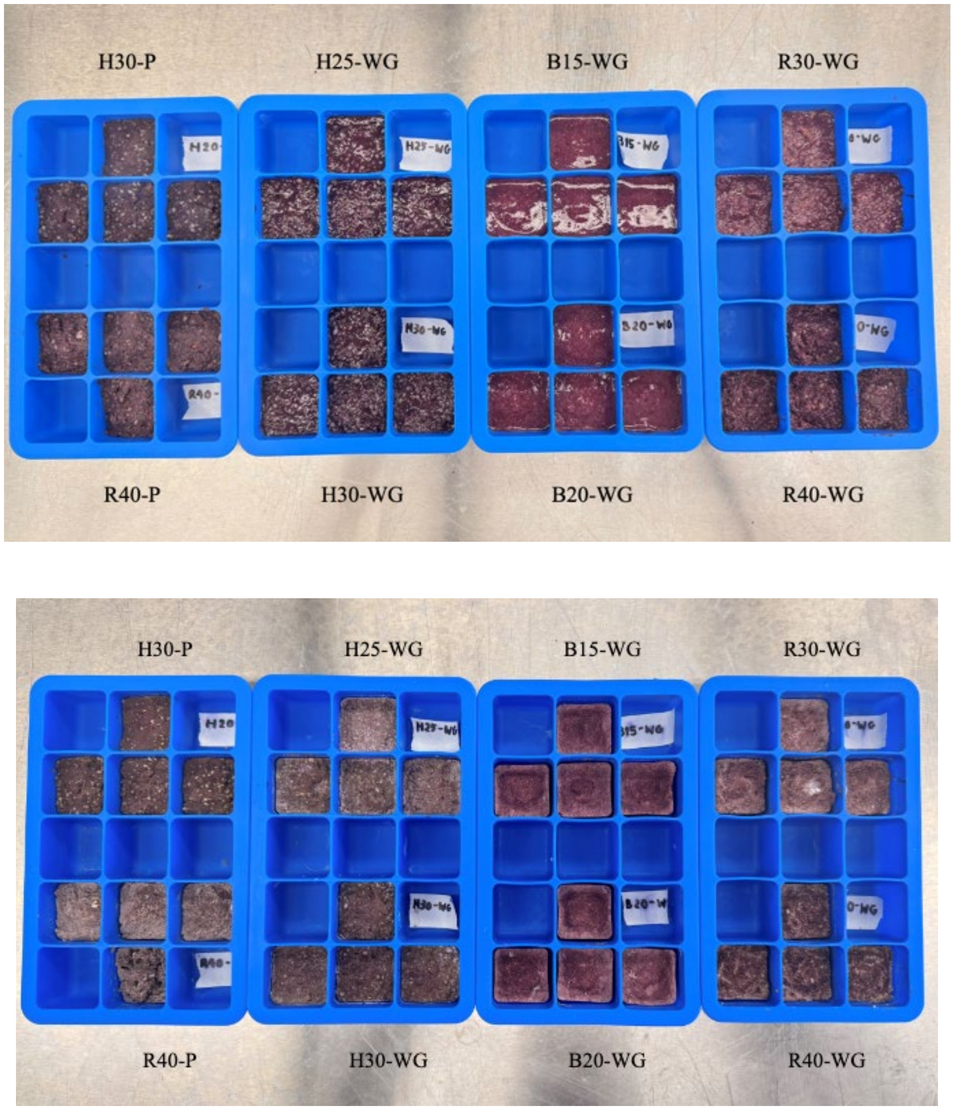


Figure 11. The mini snack bars for all formulations (grape pomace & grape puree) by freeze drying from Table 2.

Figure 12. The snack bar formulation prototypes from Table 15 with HAD (158˚F for 10 h)

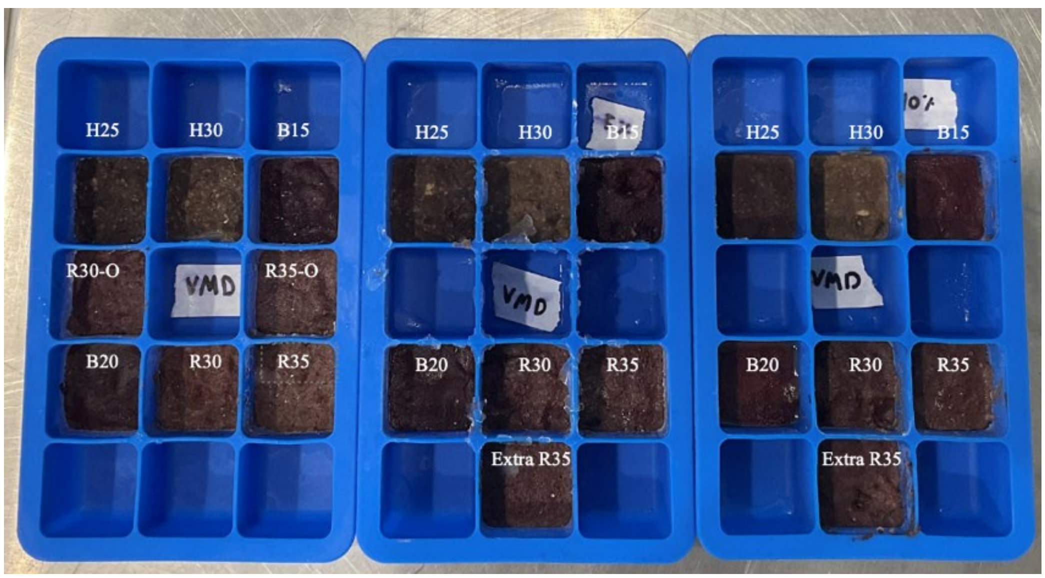


Figure 13 The pre-frozen snack bar prototypes from Table 9 after MVD at 1.5 W/g for 50 min.

Table 3 summarized the final formulations used to measure physichochemical properties of the grape snacks, as well as optimizing the 30% hemp formulation for added buckwheat as the binding agent (0 to 0.8%), optimizing the 5% buckwheat formulation for grape seed oil addition (0 to 2%), and optimizing the 12% red bean formulation for oil addition (0-10%). The preferred formulations were selected as H3 (30% hemp +0.8% buckwheat, B3 (5% buckwheat + 1.5% oil) and R3 (12% red bean + 7% oil). These formulations, dried by FD, MVD and HAD, were further characterized including nutritional analysis and sensory evaluation.

Table 3. Formulation optimization for snack bar prototyping for the three drying methods

Ingredients (g)	Bar Symbol											
	H1	H2	H3	H4	B1	B2	B3	B4	R1	R2	R3	R4
Protein source ingredient												
Roasted Hemp	30.0	30.0	30.0	30.0								
Buckwheat flour	0.0	0.5	0.8	1.0	5.0	5.0	5.0	5.0				
Red beans									12.0	12.0	12.0	12.0
Grape ingredient												
Grapeseed oil					0.0	1.0	1.5	2.0	0.0	5.0	7.0	10.0
Whole Grape Puree	70.0	69.5	69.2	69.0	95.0	94.0	93.5	93.0	88.0	83.0	81.0	78.0
Total (g)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

The nutrition labels of the three different products are shown in Figure 14. The nutritional facts highlight the differences based on the formulations, with the hemp snacks having higher fat and protein content and therefore higher calories per serving.

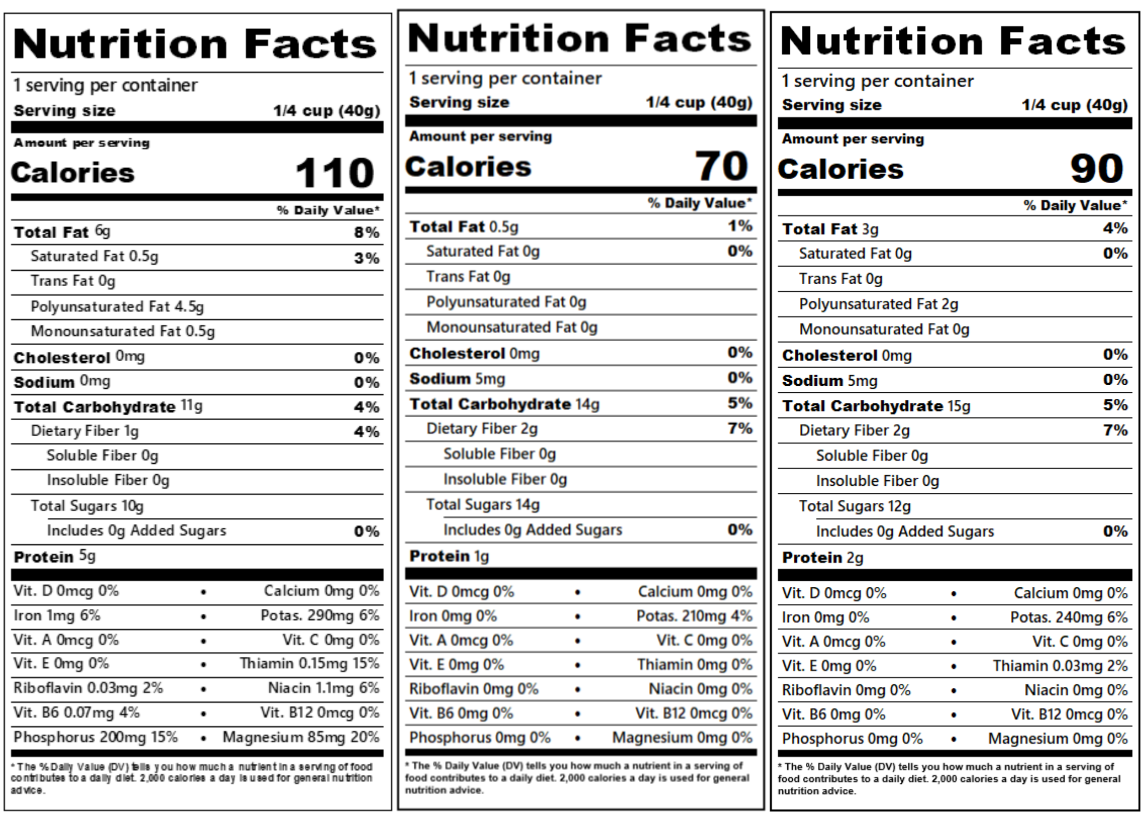


Figure 14. The Nutrition Labels for selected freeze-dried snack bars prepared with Concord grape and Hemp,

The results of the texture analysis are presented in Figures 15. Each bar represents the mean puncture force (kg) averaged across all formulations containing each grain type within each drying method. The highest puncture force was observed in HAD Buckwheat samples (A) which indicated the hardest level across all formulations. The correlation between grain type and drying methods is still unclear. The Hot Air-drying methods have notable effect and produced denser and harder snack bars comparing to FD and MVD processes. Grain type also influenced the hardness, with hemp generally exhibiting lower puncture force than buckwheat and red bean across drying methods. FD consistently resulted in the softest texture across all grains.

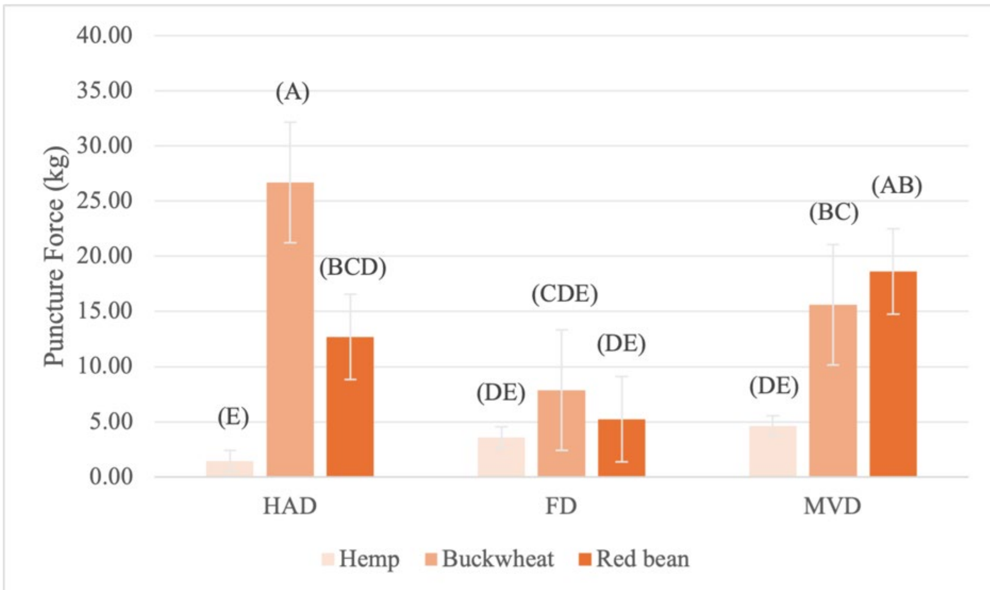


Figure 15. Puncture Force of Selected Concord Grape and Grain Snack Bars (H3,B3,R3) Prepared with Different Grains and Drying Methods (Tukey HSD, $p<0.05$). Treatments sharing the same letter are not significantly different from each other.

The physicochemical properties of the dried bars are summarized in Table 4 a-c. The phenolic content varied significantly across drying methods and protein types. For hemp, phenolic content was highest in HAD samples (798 ± 256 mg/L), followed by MVD (772 ± 59 mg/L) and FD (741 ± 173 mg/L). The higher phenolic content in HAD samples may be attributed to heat-induced breakdown of cellular structures, facilitating the release of bound phenolic. In red beans, phenolic content decreased with harsher drying methods, with FD retaining the highest levels (1590 ± 96 mg/L) and HAD showing the lowest (929 ± 234 mg/L). This trend suggests that phenolic compounds in buckwheat may be more susceptible to degradation at higher temperatures. For buckwheat, phenolic content was relatively consistent across methods, with FD (1555 ± 101 mg/L) and MVD (1570 ± 295 mg/L) showing similar numbers, likely due to reduced thermal degradation under these milder drying conditions. In red beans, phenolic obviously decreased with harsher drying methods, with FD holding the highest levels (1590 ± 96 mg/L) and HAD showing the lowest (929 ± 234 mg/L). This trend suggests that phenolic compounds in red beans may be more susceptible to degradation at higher temperatures.

Table 4a. Selected Grape and Hemp Snack Bars (69.2% whole grape puree + 30% roasted hemp + 0.8% buckwheat flour) Across All Drying Methods.

Components	FD	MVD	HAD
Phenolic content (mg/L)	741 ± 173	772 ± 59	798 ± 256
Anthocyanin (mg/L)	13.11 ± 3.94	2.72 ± 0.61	3.90 ± 0.2
pH	5.08 ± 0.01	4.96 ± 0.01	5.32 ± 0.01
L*	36.5 ± 3.4	25.99 ± 1.57	27.04 ± 0.62
a*	6.71 ± 0.39	6.81 ± 0.69	5.76 ± 0.75
b*	9.62 ± 0.30	11.25 ± 2.29	9.24 ± 0.78
ΔE*	61.37 ± 3.27	71.98 ± 1.68	7.60 ± 0.71
Puncture Force (kg)	4.03 ± 1.20	3.48 ± 1.26	3.29 ± 0.85
Water Activity	0.3557 ± 0.001	0.5894 ± 0.001	0.5948 0.001
Moisture Content (%)	1.7107	0.0652	11.2917

Table 4b. Selected Grape and Buckwheat Snack Bars Bars (93.5% whole grape puree + 5% buckwheat flour + 1.5% grape seed oil) Across All Drying Methods.

Components	FD	MVD	HAD
Phenolic content (mg/L)	1555 ± 101	1570 ± 295	1701 ± 192
Anthocyanin (mg/L)	0 ± 0	0 ± 0	0.22 ± 0.20
pH	3.44 ± 0.01	4.00 ± 0.01	3.50 ± 0.01
L*	33.63 ± 2.97	22.72 ± 3.85	19.55 ± 0.68
a*	18.78 ± 4.74	5.98 ± 2.79	2.21 ± 0.58
b*	5.30 ± 0.77	5.49 ± 0.31	3.50 ± 0.42
ΔE*	66.4 ± 1.35	74.70 ± 3.72	77.57 ± 0.66
Puncture Force (kg)	8.32 ± 2.31	14.10 ± 6.18	19.00 ± 7.87
Water Activity	0.5264 ± 0.001	0.6321 ± 0.001	0.5901 ± 0.001
Moisture Content (%)	7.5805	1.286	0.8688

Table 4c. Selected Grape and Red Bean Snack Bars (81% whole grape puree + 12% red beans + 7% grape seed oil) Across All Drying Methods.

Components	FD	MVD	HAD
Phenolic content (mg/L)	1590 ± 96	1177 ± 171	929 ± 234
Anthocyanin (mg/L)	0.28 ± 0.39	0.78 ± 1.10	0.22 ± 0.08
pH	3.93 ± 0.01	4.00 ± 0.01	4.08 ± 0.01
L*	32.13 ± 9.43	24.88 ± 1.36	21.21 ± 2.45
a*	12.53 ± 3.32	8.81 ± 1.09	4.37 ± 1.72
b*	5.10 ± 0.30	5.66 ± 0.73	5.50 ± 1.50
ΔE*	66.34 ± 8.50	72.82 ± 1.18	76.08 ± 2.27
Puncture Force (kg)	5.48 ± 1.73	20.73 ± 6.05	10.32 ± 2.21
Water Activity	0.3293 ± 0.001	0.6592 ± 0.001	0.4379 ± 0.001
Moisture Content (%)	2.56	1.98	2.61

A total of 101 untrained panelists (66% female, 29% male, 4% non-conforming,1% preferred not to disclose) were recruited from the university and surrounding community. The average age of participants was 35.22 years. Sensory evaluation results are shown in Figure 16 and 17. For hemp seed bars, freeze-dried (FD) samples were rated significantly higher than microwave vacuum-dried (MVD) samples in all sensory attributes; appearance, texture, flavor, aroma, overall liking, and color ($p < 0.05$). Panelists noted that FD Hemp bars had a more uniform texture, and a sweeter flavor profile compared to MVD Hemp bars, which were described as grainy and lacking in fruit flavor. Similarly, FD Buckwheat samples showed a slightly higher scores in most of the attributes except for the aroma. However, only the color property illustrated the significant difference. Taking into consideration of overall attributes, the result suggested that freeze drying methods gained more acceptance and better-preserved sensory characteristics in general compared to the samples treated with microwave vacuum drying method.

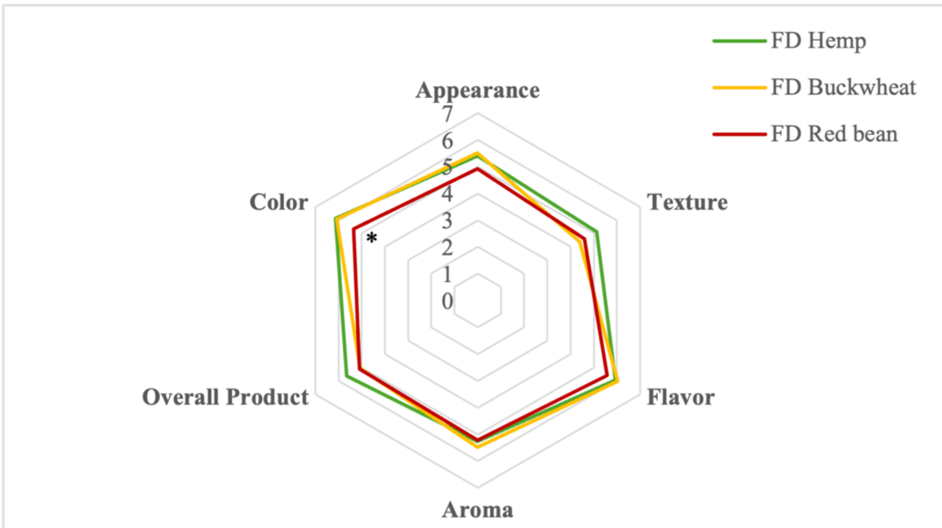
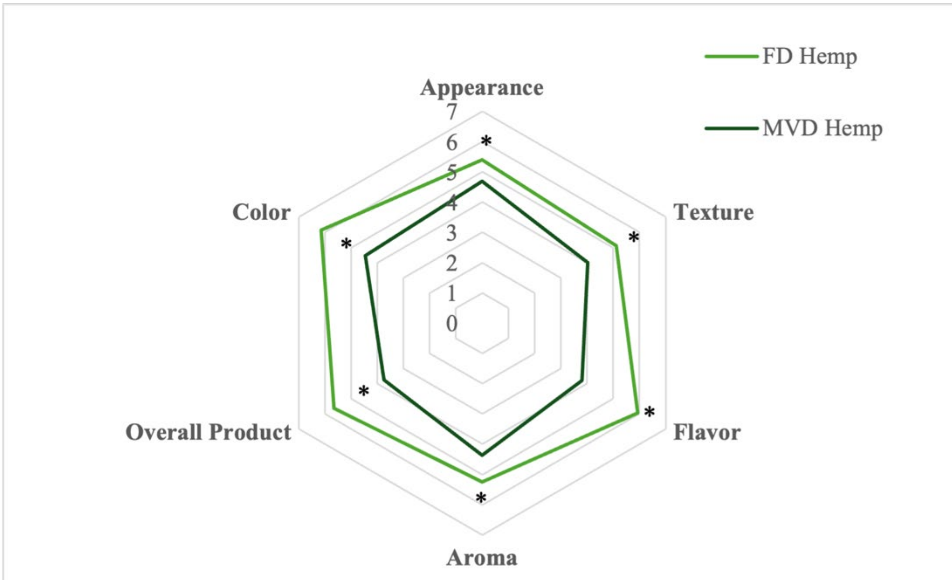


Figure 16. Sensory attribute rating of appearance, texture, flavor, aroma, overall product, and color for the Concord grape and grain snack bars comparing different type of grains with the FD methods. Denotation of "*" indicates significant difference between different grain types (n= 101, $p < 0.05$)



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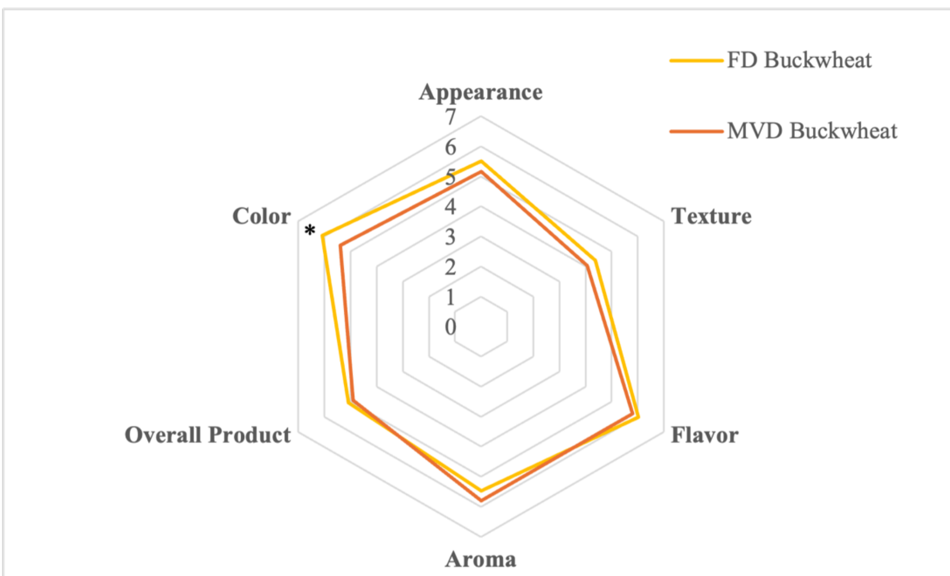

(b)

Figure 17. Sensory attribute rating of appearance, texture, flavor, aroma, overall product, and color for the Concord grape and grain snack bars comparing different type of grains with the FD methods. Denotation of "*" indicates significant difference between different drying methods (n= 101, $p < 0.05$)

Technology Transfer Plan:

The new products have been showcased in the poster showcase at the MFS graduation event at Department of Food Science at Cornell University and were welcomed. The team will reach out to collaborating grape processors and food manufacturers at a regional level (Lake Erie, Finger Lakes, and NE US) through the extension programs to disseminate the results. Dissemination of intended outcomes to stakeholders will occur by demonstrating the product manufacturing and illustrating the results at regional meetings. Instructional written deliverables, publications and online videos will be prepared for instructions, and product demonstrations will be offered through the Cornell Food Venture Center (CFVC), which will ensure high impact to a wide number of stakeholders.

SECTION 3:

Project summary and objectives: This project aimed to expand the food product lines and enhance the consumption of Concord grapes in the New York State by developing novel high-fiber, protein-rich whole-food snacks under optimized formulation and processing conditions. Two liquid shakes and three dried snack bars were formulated, then manufactured using advanced thermal and nonthermal technologies. The physical chemical properties and sensory qualities of the products were systematically evaluated. Two Master of Food Science students were professionally trained and graduated, and two posters were presented in the IFT annual international meeting.

Importance of research to the NY wine industry:
Concord grape is an important specialty crop to the NYS's agricultural economy, and important food source. This project focuses on developing high-fiber, protein-rich snacks from whole Concord grapes and sustainable protein sources using advanced processing and preservation technologies. It follows modern diet trends and provides the consumers with a healthier snack and a new way of consuming Concord grapes. The new products can be included in school meals and contribute to improve diet balance and nutrition security among the young generations at a regional level, with potential downstream benefits at the national level. It is expected that this will encourage more consumption of Concord grapes and therefore, increase demand for their production.

Project Results/next steps:
The results showed that both HT and HPP significantly impacted the anthocyanin content, with HT generally causing greater anthocyanin degradation than HPP, particularly at higher protein concentrations. For pea protein formulations, HPP-treated samples at 4% and 6% protein concentrations retained more anthocyanins compared to HT, but at 8% protein concentration, both methods significantly reduced TMA. Chickpea protein formulations followed similar trends, with significant TMA reductions observed at higher protein concentrations for both HT and HPP. In terms of color stability, HPP-treated samples exhibited more noticeable color changes compared to HT, especially at higher protein concentrations. Viscosity analysis revealed that HT increased viscosity significantly, particularly in higher protein formulations, while HPP had a more moderate impact on viscosity.

Main component of the snack bars was Concord grape ranging from 69 to 93.5%. FD retained the highest phenolic content for red bean bars (1590 ± 96 mg/L), while HAD yielded the highest for hemp bars (798 ± 256 mg/L). Anthocyanin content was highest in FD hemp bars (13.1 ± 3.9 mg/L) but showing significant losses due to higher temperatures in other methods. Textural analysis revealed MVD produced the hardest bars (20.7 ± 6.0 kg for red bean), while FD maintained softer textures, particularly for hemp (4.0 ± 1.2 kg). MVD samples exhibited the lowest moisture content (0.065% in hemp), ensuring microbial stability but negatively impacting sensory appeal. With 101 panelists in sensory evaluation, the FD formulations were most preferred across most attributes. FD hemp bars were rated higher for flavor and overall liking, while MVD hemp bars faced penalties for insufficient fruit flavor (mean drop of 2.3 points, detected by 80% of participants). Texture issues, such as excessive hardness or insufficient crunch in a bar snack type, were critical drivers of consumer disliking in both FD and MVD samples.

Next steps will mainly focus on disseminating the results via peer review publications and extension and outreach activities.

Supporting attachments: