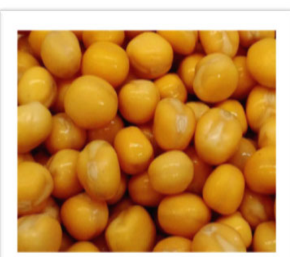
2022

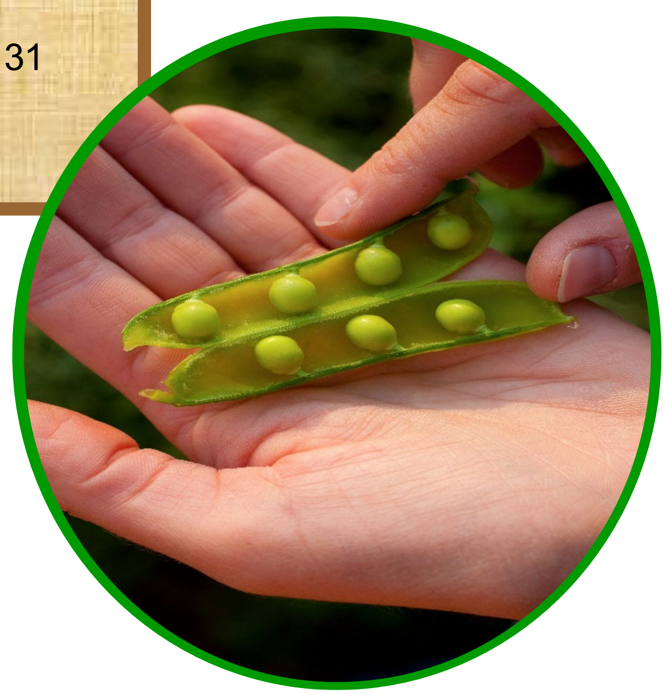
U.S. Pulse Quality Survey



Northern Pulse Growers Association

USA Dry Pea & Lentil Council

Contents



2022 Overview and Author's Comments

Summary Points

1. The 2022 pulse quality report represents the 15th variation of a pulse quality evaluation started by the Northern Crops Institute in 2008. Data in this report includes both 5- and 10-year mean data where available. The 10-year mean represents a long-term assessment of quality.
2. Data from approximately 53 samples received from major US pulse growing regions were evaluated. Mixed growing conditions (some dry and some exceedingly wet) had a significant impact on sample collection in 2022.
3. Six functionality tests and a RVA gel firmness value were reported for the first time in 2022.
4. Significant impacts on protein (higher percentage) and starch (lower percentage) were observed in all three pulses.
5. With the exception of winter peas, peas overall had significantly lower 1000 seed weights in 2022.
6. Peas and green lentil had higher water hydration capacities compared to long-term mean values. Whereas Spanish brown lentils and chickpeas had comparable water hydration capacities to the long-term mean values.
7. All three pulses had lower pasting viscosities compared to long-term mean values which indicates thinner pastes resulted in 2022.

This report provides a summary of the 2022 pulse crop quality for dry pea, lentil and chickpea grown commercially in the USA. In 2022, a total of 53 pulse samples were collected from the major US pulse growing regions. The seeds evaluated included 20 dry pea, 18 lentil, and 25 chickpea samples, which were acquired from pulses growers and industry representatives in pulse growing areas in Idaho, Montana, North Dakota, South Dakota, and Washington.

According to the USDA National Agricultural Statistics Service and the U.S. Dry Pea and Lentil Council, pulse harvested acres and estimated total production for 2022 was 1.81 million acres and approximately 1.1 million metric tons, respectively. Pulse acres in 2022 was higher compared to the 2020 and 2021 harvest but lower than acres harvested in 2018 and 2019. Pea and lentil harvested acres and production were higher in 2022 compared to 2021 while chickpea harvested acres and production were lower in 2022 compared to 2021.

The quality is grouped into three main categories, which include proximate composition, physical parameters, and functional characteristics. The canning quality was also a separate category. Proximate quality parameters include ash, fat, moisture, protein, and total starch content. Water hydration capacity, percentage unhydrated seeds, swelling capacity, cooked firmness, test weight, 1000 seed weight, size distribution and color represent the physical parameters. The pasting characteristics represent the functional characteristics of the pulses. In addition, 6 new functionality tests were completed in 2022. These include emulsion activity and stability, foaming capacity and stability, water holding capacity and oil holding capacity.

Results from the proximate (i.e., moisture, protein, etc.) composition analyses indicated that results were mixed and did not follow closely the results from any one previous year. However, some results were comparable to 5- and 10-year mean data.

In general, pea, lentil, and chickpea from 2022 had the same or lower moisture contents compared to pulses from previous crop years. Pea and chickpea had moisture contents lower than the 5-year mean moisture values. However, the moisture contents of the pulses from 2022 tended to match the 10-year mean moisture contents of their respective pulse crop. This suggests that the long-term moisture is a good guide to predicting moisture content of a pulse. In contrast, the total starch contents of all three pulses were significantly lower in 2022 compared to the 10-year mean starch content. The total starch percentages in lentils from 2022 was not comparable to the lentils harvested in previous years while total starch in peas and chickpeas grown in 2022 had comparable starch contents to peas from 2018 and 2021 and chickpea from 2018. The total starch of peas and chickpea from 2022 had mean total starch contents that were midway between the 5- and 10-year mean total starch content. In contrast, the mean total starch of the lentils from 2022 was less than both the 5- and 10-year mean total starch content. The winter pea class had total starch that were significantly lower than winter peas from previous production years. Both lentil classes had lower mean total starch contents in 2022 compare to their respective 5- and 10-year mean values. The mean protein content in peas from 2022 was higher than for pulses from recent years, including the 5- and 10-year mean protein contents. Protein content from green peas most closely matched those from the 2020 and 2021 harvest years. Like 2021, the yellow peas from 2022 had significantly higher protein content than yellow peas from other harvest years. Lentils from 2022 had protein contents similar to lentils from 2020. The protein content in the 2022 chickpeas was higher than both the 5- and 10-year mean values. Collectively, the protein data from recent years supports higher protein compared to the long term mean value with only a few exceptions. The fat contents of the pulses evaluated were within ranges reported in the literature. The mean fat contents of peas and lentils from 2022 were lower than their respective crops from previous years except 2021. In contrast, the mean fat content of chickpeas from 2022 matched the mean fat contents of chickpeas from 2020 and 2021.

The physical parameters such as water hydration capacity, test weight, and color analysis of the pulses from 2022 had varying results compared to previous pulse crops. Overall, the mean test weight of peas and lentils were lower and higher, respectively, than their 5- and 10-year mean test weights. The chickpea mean test weight in 2022 match the 5- and 10-year mean test weight. The most significant change in physical parameter in 2022 was the 1000 seed weight of peas. The 1000 seed weight was approximately 30 g less in 2022 compared to the 5- and 10-year mean 1000 seed weight. In contrast, lentils and chickpeas had 1000 seed weight that were either comparable or higher than the 5- and 10-year mean values. The water hydration capacities in 2022 were higher than the 5- and 10-year mean values for peas but comparable to the 5-year mean for lentil and chickpea. Swelling capacity of lentils and chickpeas from 2022 were lower than the 5-year mean values while peas had essentially the same swelling capacity as the 5-year mean swelling capacity. A size distribution analysis of chickpea indicated a larger seed size for chickpea from 2022. The Royal chickpea cultivar had the highest percentage (89.7%) of seeds retained on a 22/64-inch sieve in 2022. Overall, the chickpea from 2022 had the highest percentage of seeds being retained on the 22/64- and 20/64-inch sieves supporting the larger seed size in 2022 compared to the three previous years. Cooked firmness values of green and yellow peas were higher than peas from previous crop years while winter peas had significantly lower cooked firmness in 2022. Lentils had cooked firmness values comparable to the 5-year mean value while chickpea had lower firmness values except for chickpea from 2020 and 2021.

The color of the peas in 2022 were lighter than peas from other harvest years except 2020. The lighter color was supported by higher lightness (L*) values. The color difference values of dry peas vs. soaked peas from 2022 were comparable to the peas from 2020 and the 5-year mean color difference value for both green and yellow peas. The color tended to be lighter for all lentils regardless of lentil color. This might be the result of the samples having less greenness (i.e., a* value) compared to previous years. The 2022 chickpea crop had slightly higher lightness values compared to the 5-year mean but had L* values less than the 10-year mean L* value. However, the yellowness values (b* value) of chickpea from 2022 were significantly lower than 5- and 10-year mean yellowness value. Overall, the color difference between dry and soaked chickpea was lower than the 5-year mean value.

The starch pasting properties for the 2022 peas and lentils were the most significantly different from previous years except 2021. The peak, hot and cold paste viscosities were all significantly lower than peas and lentils from previous years. The paste that resulted from the pea and lentil flours was less viscous than the paste from their flours from other crop years. Furthermore, chickpea from 2022 had pasting properties lower than the 5- and 10-year mean values. New in 2022 was the addition of a RVA gel firmness test. Lentils had gels with the highest firmness (285 g) followed by chickpeas (272 g) and peas (242 g). Other functionality tests new to 2022 showed that emulsion activity and stability did not differ significantly among the pulse samples. The water holding and oil holding capacities of chickpea (1.01 and 0.25 g/g) were lower than the values for peas (1.28 and 0.37 g/g) and lentils (1.30 and 0.40 g/g). This suggests that chickpea is less able to bind water and oil compared to peas and lentils. The greatest foaming capacity was observed in peas (215%) followed by lentils (205%) and chickpea (164%). However, foam stability was greatest for chickpea (85%) followed by lentils (67%) and peas (62%).

Overall, the canning quality of pea from 2022 was significantly different from the previous canning evaluation. The water hydration capacity of canned peas in 2022 was significantly higher than peas from 2018-2021 (except 2019) and the 5-year mean values while swelling capacity was lower. Canning firmness was significantly lower (i.e., less firm) in 2022 compared to peas from 2020 and 2021 and the 5-year mean value. Chickpeas from 2022 had hydration capacity and swelling capacity similar to canned chickpeas from 2019. The mean canned firmness of chickpea from 2022 was 6.6 N/g, which is lower than the 5-year mean canned firmness.

The focus of the pulse program is the quality evaluation and utilization of pulses as food and food ingredients. The mission of the Pulse Quality Program is to provide industry, academic and government personnel with readily accessible data on pulse quality and to provide science-based evidence for the utilization of pulses as whole food and as ingredients in food products. The data provided has been reported for a number of years. I welcome any thoughts, comment, and suggestions regarding the report. If a quality trait is of interest, please reach out to me. I would like to thank the USA pulse producers for their support of this survey.

Sincerely,
Clifford Hall, Ph.D.
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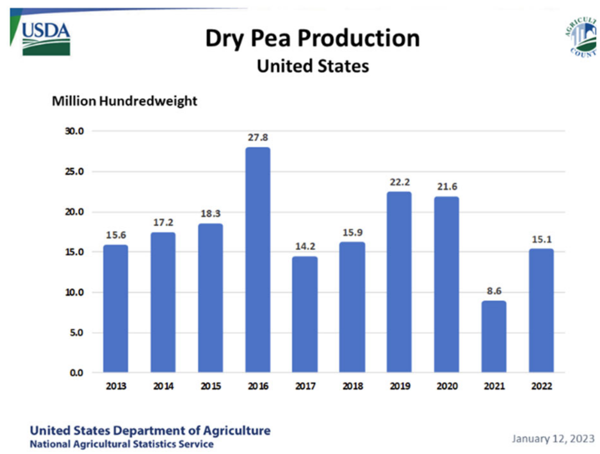
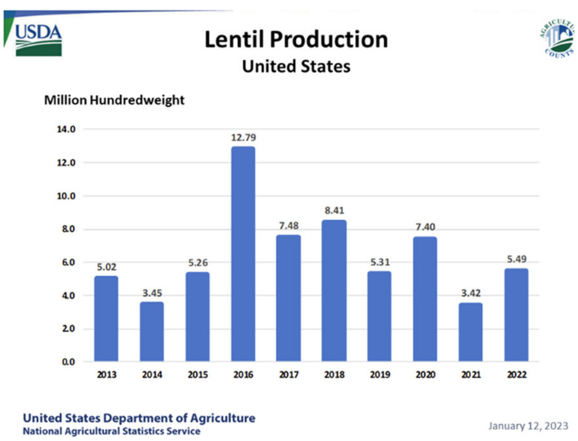
Pulse Production

Northern Plains region and Pacific Northwest are the largest pulse producing area within the USA. US pulse harvested acreage in 2022 was 1,805,900 (Table 1), which was approximately 70 thousand more acres than in 2021 but 80 thousand less acres than in 2019. Total US pulse production (Metric Tons (MT)) in 2022 is estimated to be 1,050,838 which is down significantly from the 1,357,838 produced in 2020 but up significantly from 2021 (Table 1). The conditions affecting some of the pulse growing regions likely contributed to the lower production compared to the previous crop years (2018-2020). The UDSA estimated that the dry pea acreage was 862,000, which was down from the 919,000 in 2020 but greater than the 834,000 from 2021(Table 1). Pea production (684,562 MT) was less than the previous production of 941,571 MT in 2020 but significantly more than in 2021(Table 1). The long-term production shows that the 15.1 million 100-weight of peas produced matched the 2017 and 2018 levels.



Lentil acreage was 602,000 in 2022 and represents the most acres since 2018 (Table 1). Lentil production in 2022 was 248,977 MT, which nearly doubled the 2021 production of 150,912 MT. The 2022 production fell between the 230,881 and 273,723 MT production in 2020 and 2019, respectively. The USDA estimate of 5.49 million 100-weight of lentil match 2019 production levels but not those from 2016-2018. Chickpea harvested acres (341,900) in 2022 was lower than the 2021 production of 351,000 acres. Production was estimated at 117,299 MT, which is lower than the production from previous years (Table 1). Furthermore, the production of large chickpea nearly doubled the production of small chickpea.



The lower production of pulses supports decrease in yields per acres. The drought experienced in some parts of the growing region had a significant and primary role in the low production of the pulse crops. The yield for dry pea was 1751 lbs./acre in 2022, which is up from the 1,021 lbs./acre in 2021 but down from approximately 2000 lbs./acre in 2018-2020. Lentil yield rebounded from 606 lbs./acre in 2021 to approximately 900 lbs./acre in 2022. However, this value is still lower than the 2020 yield of 1,338 lbs./acre. Like peas and lentils, chickpea yield (~1100 lbs./acre) rebounded slight from the low (815 lbs./acre) for the chickpea crop in 2021. Again, the yield was still lower than the 1630 lbs./acre in 2020 and 1,544 and 1511 lbs./acre in 2019 and 2018, respectively. The mixed moisture attained during the growing season significantly impacted production and demonstrates the importance in the production of pulses.

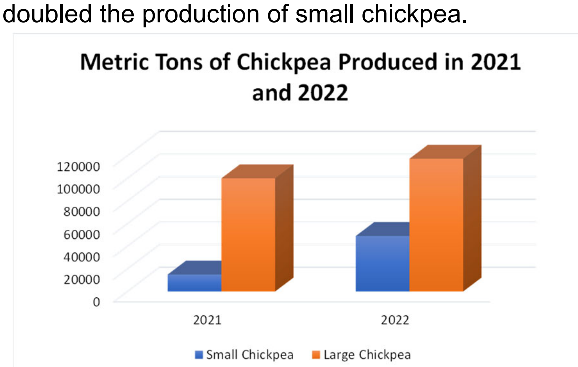


Table 1. United states pulses acreage and production summary for 2018-2022.

	2022		2021		2020		2019		2018	
Crop	Acreage*	Production**	Acreage*	Production**	Acreage	Production**	Acreage	Production**	Acreage	Production**
Dry Peas	862,000	684,562	834,000	387,780	919,000	941,571	1,052,000	1,135,229	836,400	635,936
Lentil	602,000	248,977	549,000	150,912	510,000	230,881	431,000	273,723	758,000	398,572
Chickpea	341,900	117,299	351,000	129,774	250,800	185,386	404,000	316,854	651,300	425,870
Total	1,805,900	1,050,838	1,734,000	668,466	1,679,800	1,357,838	1,887,000	1,725,806	2,245,700	1,460,378

*Acreage = Acres Harvested, **Production = Metric Tons, Source: USDA NASS (2023)/ US Dry Pea and Lentil Council

Laboratory Methods Used to Measure Pulse Quality

Where applicable, standard methods were followed for the determination of each pulse quality attribute in 2022 (Table 2). For most analyses, data is provided on data collected between 2018 and 2022. The data is reported as a range, mean and standard deviation (SD) for the 2022 harvest year while preceding years were provided as a means plus SD. Data on cultivars was reported only for the 2022 harvest years and no comparisons were made in the tables to cultivars from the previous year. A summary of the testing methods can be found in table 2. Further information of the testing methods is provided below.

- Moisture content is the quantity of water (i.e., moisture) present in a sample and is expressed as a percentage. Moisture content is an important indicator of pulse seed handling and storability. Generally, pulse crops are recommended for harvest at 13-14% moisture. At lower moisture levels, the seeds are prone to mechanical damage such as fracturing. Pulses with higher moisture levels are more susceptible to enzymatic activity and microbial growth, which reduce quality and increase food safety risks.
- Pulses are rich in protein, which ranges from 20 to 30% depending on the growing location, cultivar, and year. Pulses are low in sulfur-containing amino acids but high in lysine, an essential amino acid for human health. Protein content is the quantity of protein present in a sample and is expressed as a percentage.
- The fat (i.e., lipid) content is the quantity of fat present in the pulse. Usually, peas and lentils have fat contents under 3% while chickpea contain 5-10%.
- Ash content is the quantity of ash present in a sample and is expressed as a percentage. Ash is an indicator of minerals. Higher ash content indicates higher amounts of minerals such as iron, zinc, and selenium. The specific mineral analysis provides information in mg/kg levels.
- Total starch is a measure of the quantity of starch present in a sample and is expressed as a percentage. Starch is responsible for a significant part of the pulse functionality such as gel formation and viscosity enhancement. Enzymatic hydrolysis is the basis for the starch determination. Starch functionality is measured using the RVA instrument. Pulses show a type C pasting profile, which is represented by a minimally definable pasting peak, a small breakdown in viscosity and high final peak viscosity. This type of starch is ideal for glass noodle production.
- Test weight and 1000 seed weight are indicators of seed density, size, shape, and milling yield. Each pulse crop has its own market preference based on color, seed size, and shape. A grain analysis computer is used to determine test weight in lbs./bu.
- Water hydration capacity, percentage unhydrated seeds, and swelling capacity are physical characteristics of pulses that relate to the ability of the pulse to re-hydrate. The swelling capacity relates to the increased size of the pulse as a result of rehydration. Cooking firmness provides information on the texture (i.e., firmness) of the pulse after a cooking process. The data obtained can be used to predict how a pulse might change during cooking and canning processes.
- Color analysis is provided as L*, a* and b* values. Color analysis is important as it provides information about general pulse color and color stability during processing. Color difference is used specifically to indicate how a process affects color. In this report, a color difference between pre- and post-soaked pulses was determined.
    - "L*" represents the lightness on a scale where 100 is considered a perfect white and 0 for black. Pulses such as chickpeas and yellow peas typically have higher L* values than green or red pulses. The "a*" value represents positive for redness and negative for green and "b*" represents positive for yellow, negative for blue and zero for gray. A pulse with a higher positive "b*" value would be indicative of a yellow pulse while a higher "a*" value represents a pulse with a red-like hue, thus brown pulses have a higher red value than a yellow pulse. Green pulses have negative "a*" values and thus the greater the negative value, the greener the pulse.
- Canning quality evaluation. This evaluation serves as an Indicator of pulse quality after a canning process and a three-week storage. The information allows for a relative difference in quality to be established following a canning process that used a brine solution containing calcium chloride.
- Functionality testing was new in 2022. The functionality included emulsion activity and stability, foaming capacity and stability, water holding capacity and oil holding capacity.
    - Emulsions are heterogenous combination or dispersion of two or more immiscible liquids, usually oil and water, that are formed with the aid of mechanical agitation. Stability of an emulsion is simply a gravitational separation of the two primary phases of a mixture.
    - Foams are dispersion of gas bubbles in a liquid or solid phase. Foaming capacity is the amount of interfacial area that can be created by whipping the flour. Foam stability is defined as the time needed to lose 50% of either liquid or volume of foam. These properties can be important for products such as cakes.
    - Water holding capacity and oil holding capacity are measures that allow for the determination of the amount of water or oil that can bind to the flour. This information is important because it allows product developers to identify how much water or oil maybe taken up by a flour and thus allow them to adjust formulations as needed.

Table 2. Quality attribute, analytical method, and remarks for analyses conducted for the 2022 pulse quality survey.

Quality Attribute	Method	Remarks
1. Moisture (%)	AACC Approved Method of Analysis, Method 44-15.02	Indicator of post-harvest stability, milling yield and general processing requirements.
2. Protein (%)	AACC Approved Method of Analysis, Method 46-30.01	Indicator of nutritional quality and amount of protein available for recovery.
3. Ash (%)	AACC Approved Method of Analysis, Methods 08-01.01	Indicator of total non-specific mineral content.
4. Total starch (%)	AACC Approved Method of Analysis, Method 76-13.01	Indicator of nutritional quality and amount of starch available for recovery.
5. Fat (Lipid)	AOCS Method Ba 3-38	Indicator of nutritional quality as related to the amount of fat in the samples.
6. Test weight (lb/bu)	AACC Approved Method of Analysis, Method 55-10.01	Indicator of sample density, size, and shape.
7. 1000 seed weight (g)	100-kernel sample weight times 10	Indicator of grain size and milling yield.
8. Chickpea Size Determination	Four samples of 250 seeds of chickpea were placed on a series of sieves (22/64", 20/64", 18/64") and rotated. The number of seed retain on each sieve was determined and reported as % of seed retained.	Indication of the size distribution within a sample of chickpea.
9. Water hydration capacity (%)	AACC Approved Method of Analysis, Method 57-12.02	Indicator of cooking and canning behavior.
10. Unhydrated seed (%)	AACC Approved Method of Analysis, Method 57-12.02	Indicator of cooking and canning behavior and the number of seeds that may not rehydrate.
11. Swelling Capacity (%)	Determined by measuring the volume before hydration (i.e., soaking) and after. The percentage increase was then determined.	Indicator of the amount of volume regained by a pulse after being re-hydrated.
12. Color	Konica Minolta CR-410 Chroma meter. The L*, a* and b* values were recorded.	Indicator of visual quality and the effect of processing on color.
13. Color Difference (ΔE^*ab)	The color difference between the dried (pre-soaked) and the soaked pulse was determined using L*, a* and b* values from the color analysis as follows (*Minolta*): $\Delta E^*ab = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$	Indicator of general color difference between pre- and post-soaked pulses. The lower the value, the more stable is the color.
14. Starch Properties (RVU)	Rapid Visco Analyzer following a modified AACC Approved Method 61-02.01. Modification included a different heating profile and longer running time. Gel firmness was completed 2 hours after the RVA. Sample was compressed at a speed of 4 mm/s to a distance of 15 mm and trigger force of 2 g with a cylindrical plunger (diameter=10 mm)	Indicator of texture, firmness, and gelatinization properties of the starch.
15. Cook Firmness	AACC Approved Method of Analysis, Method 57-14.01	Indicator of pulse firmness after a cooking process. The information allows for a relative difference in texture to be established.
16. Emulsion Properties	Maskus, et al. (2016). Cereal Foods World. 61(2): 59-64.	Indicator of the ability of the flour to facilitate the formation of an emulsion from oil and water when subjected to shear.
17. Foaming Properties	Stone, et al. (2015). Food Research International 76:31-38.	Indicator of the ability of the flour to foam when flour or protein is made into a solution and subjected to shear.
18. Water Holding Capacity	AACC Approved Method of Analysis, Method 57-13.01.	Indicator of the weight of water that will bind to one gram flour. Important parameter for producing meat and bakery products.
19. Oil Holding Capacity	Method of Wang et al. (2020). Cereal Chemistry 97:1111-1117.	Indicator of the weight of oil that will bind to one gram flour. Important parameter for producing meat and salad dressing products.
20. Canning Quality	Followed methods associated with quality attributes 9, 11, 13 and 15. Canning was completed in laminated metal cans using calcium chloride brine and processing 20 minutes and 20 psi for pea and 70 minutes at 20 psi for chickpea.	Indicator of pulse quality after a canning process and 3-week storage. The information allows for a relative difference in quality to be established following a canning process that used a brine solution containing calcium chloride.

Dry Pea Quality Results

Sample distribution

A total of 20 dry pea samples were collected from Montana, North Dakota, and Washington from August 2022 to January 2023. Samples were delivered to SDSU between January 2023 and April 2023. Growing location, number of samples, market class, and genotype details of these dry pea samples are provided in Table 3. The majority of the pea samples were obtained from North Dakota and Washington. Green peas accounted for 6 of the samples collected, where Shamrock accounted for 2 of the green peas will other samples were a mix of cultivars/varieties.

Yellow peas accounted for 6 of the pea samples collected. The samples collected were a mix of cultivars listed in table 3. Winter (8) peas were evaluated in 2022. The Blaze cultivar accounted for all samples evaluated.

Table 3. Description of dry pea samples used in the 2022 pulse quality survey.

State	No. of Samples	Market Class	Cultivars	
Montana	1	Yellow	Salamanca	
North Dakota	9	Green	ND Victory	Shamrock
			NDP150412G	
		Yellow	AAC Chrome	AAC Julius
			NDP140510Y	NDP150231Y
			Pizzaz	
Washington	10	Green	Banner	Ginny 2
		Winter	Blaze (Yellow)	

Proximate composition of dry pea (Tables 4-6)

Moisture

The moisture content of dry pea ranged from 7.7-11.2% in 2022 (Table 4). The mean moisture content of all pea samples was 9.3%, which is lower than the 5-year mean of 10.3% and the 10-year mean (9.8%). The moisture content is lower than the 14% recommended for general storability; however, long term storage under dry conditions could reduce seed moisture to lower levels where damage during storage and handling could occur. In 2022, no samples had a moisture content greater than 13%. Most pea samples had moisture contents between 9.5% and 10%. Unlike 2021, the mean the moisture contents between the three market/color classes were nearly identical. Mean moisture contents ranged from 9.2% in winter peas to 9.4% for the green peas (Table 5). The green seed moisture percentage of 9.4 was comparable to both the 5- and 10-year mean moisture contents of 9.7 and 9.3% respectively. The yellow peas mean moisture percentage was 9.3, which was over 1 percentage point lower than the 5- and 10-year mean values (Table 5). Winter peas had higher moisture percentages in 2022 compared to winter peas from 2020 and 2021 but comparable moisture content to winter peas from 2018 and 2019.

Table 4. Proximate composition of dry pea grown in the USA, 2018-2022 plus the 5- and 10-year mean values.

Proximate Composition	Year							
	2022		2021	2020	2019	2018	5-year	10-year
(%)*	Range	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Moisture	7.7-11.2	9.3 (1.1)	9.7 (1.3)	9.5 (1.3)	12.4 (1.7)	9.6 (1.0)	10.3 (1.2)	9.8 (1.7)
Ash	2.5-3.0	2.8 (0.1)	2.6 (0.2)	2.5 (0.5)	2.4 (0.2)	2.5 (0.2)	2.5 (0.1)	2.5 (0.1)
Fat	0.9-1.6	1.2 (0.2)	1.0 (0.2)	1.7 (0.6)	2.0 (0.4)	2.8 (0.8)	1.9 (0.7)	**
Protein	21.0-26.5	23.4 (1.5)	23.1 (1.1)	21.4 (1.5)	21.0 (1.4)	21.4 (1.6)	21.8 (0.8)	22.3 (1.7)
Total Starch	35.6-46.9	42.6 (3.2)	42.9 (1.9)	44.4 (3.1)	43.3 (1.5)	42.5 (1.9)	43.1 (0.9)	44.9 (3.8)

*Composition is on an "as is" basis; **not previously reported prior to 2017.

The highest moisture content was observed in the Banner and Ginny 2 (i.e., green pea) and AAC Chrome and AAC Julius (yellow pea) cultivars (Table 6). All other peas had values less than 10%. Blaze was the only cultivar of winter pea evaluated; however, the moisture values varied between 8.6 and 9.9%.

Table 5. Proximate composition of different market classes of dry pea grown in the USA, 2018-2022 plus 5- and 10-year mean values.

Proximate Composition (%)*	Mean (SD) of green pea					5-year Mean (SD)	10-year Mean (SD)
	2022	2021	2020	2019	2018		
Moisture	9.4 (1.5)	9.4 (0.9)	9.2 (1.3)	11.5 (1.8)	9.2 (1.1)	9.7 (1.0)	9.3(1.7)
Ash	2.8 (0.2)	2.6 (0.2)	2.6 (0.3)	2.4 (1.8)	2.5 (0.2)	2.5 (0.1)	2.5 (0.1)
Fat	1.2 (0.2)	1.0 (0.2)	1.6 (0.6)	2.1 (0.3)	2.9 (0.8)	1.9 (0.7)	nd
Protein	23.2 (2.1)	23.3 (1.0)	23.5 (1.3)	21.3 (0.2)	22.0 (1.8)	22.3 (1.0)	22.5 (1.3)
Total Starch	43.1 (2.2)	42.7 (1.4)	45.1 (3.0)	43.1 (1.5)	42.3 (1.6)	42.9 (1.4)	44.7 (4.3)
Proximate Composition (%)*	**Mean (SD) of yellow pea**					**5-year Mean (SD)**	**10-year Mean (SD)**
	2022	**2021**	**2020**	**2019**	**2018**		
Moisture	9.3 (1.4)	10.8 (0.6)	9.9 (1.1)	12.9 (1.4)	9.9 (0.9)	10.7 (1.3)	10.3 (1.6)
Ash	2.8 (0.1)	2.5 (0.1)	2.4 (0.6)	2.4 (1.2)	2.5 (0.2)	2.5 (0.1)	2.5 (0.1)
Fat	1.2 (0.1)	1.1 (0.1)	1.7 (0.6)	1.9 (0.4)	2.7 (0.8)	1.9 (0.6)	nd
Protein	22.6 (0.9)	23.0 (1.0)	21.4 (1.3)	20.8 (0.2)	21.1 (1.5)	21.5 (0.9)	21.8 (1.5)
Total Starch	45.6 (1.1)	43.5 (2.5)	43.9 (3.0)	43.4 (1.5)	42.6 (2.0)	44.5 (3.5)	43.1 (0.7)
Proximate Composition (%)*	**Mean (SD) of winter pea**					**5-year Mean (SD)**	**10-year Mean (SD)**
	2022	**2021**	**2020**	**2019**	**2018**		
Moisture	9.2 (0.5)	8.4 (0.9)	7.8 (0.9)	9.5 (0.2)	9.5 (0.2)	nd	nd
Ash	2.9 (0.1)	2.7 (0.2)	2.5 (0.1)	2.5 (1.2)	2.5 (1.2)	nd	nd
Fat	1.1 (0.1)	0.8 (0.1)	1.7 (0.4)	1.9 (0.1)	1.9 (0.1)	nd	nd
Protein	24.1 (1.2)	23.1 (1.5)	21.3 (1.3)	21.3 (0)	21.3 (0)	nd	nd
Total Starch	40.0 (2.8)	43.5 (1.3)	46.1 (2.4)	42.5 (1.2)	42.5 (1.2)	nd	nd

*composition is on an "as is" basis; nd = not determined due to test not being performed for 5 or 10 years.

Ash

The ash content of dry pea ranged from 2.5 to 3.0%, with a mean of 2.8%. The mean ash content (2.8%) of dry peas grown in 2022 was approximately the same as the 5- and 10-year mean ash contents of 2.5% (Table 4). Ash content is a general indicator of minerals present and has been consistent over the ten-year evaluation of peas. The ash contents of green and yellow peas were both 2.8% (Table 5). The green and yellow pea ash contents were slightly higher than their respective 5- and 10- year mean ash values of 2.5%. Winter peas had a 2.9% ash content, which was higher than the mean ash content from previous years (Table 5). The ash percentage in individual samples ranged from 2.5% in Banner and Ginny 2 to 3.0% in ND Victory and NDP150412G (Table 6). However, minimal (less than 0.2 percentage points) variability in ash content was observed among the samples of Blaze winter peas (Table 6).

Table 6. Mean proximate composition of dry pea cultivars grown in the USA in 2022.

Market Class	Cultivar	Concentration (%)				
		Moisture	Ash	Fat	Protein	Starch
Green	Banner*	10.7	2.5	1.6	21.0	40.6
	Ginny 2*	10.4	2.5	1.2	22.8	41.5
	ND Victory*	7.9	3.0	1.3	22.2	46.7
	NDP150412G*	7.7	3.0	1.1	24.9	43.6
	Shamrock	9.8	2.7	1.1	24.1	43.1
Yellow	AAC Chrome*	10.6	2.6	1.2	21.1	45.0
	AAC Julius*	11.2	2.9	1.2	22.0	45.0
	NDP140510Y*	7.8	2.7	1.1	22.9	46.9
	NDP150231Y*	8.0	2.9	1.3	22.8	44.1
	Pizzaz*	9.8	2.8	1.3	23.1	46.7
	Salamanca*	8.5	2.7	1.0	23.5	46.2
Winter	Blaze	9.2	2.9	1.1	24.1	40.0

*Only one sample of cultivar tested

Fat (Lipid)

The fat content of dry pea ranged from 0.9 to 1.6%, with a mean of 1.2% (Table 4). The mean fat content (1.2%) of pea harvested in 2022 was lower than fat content of pea harvested in previous years except from 2021. In addition, the fat content (1.2%) was lower than the 5-year mean fat content (1.9%). The fat contents of the green and yellow market classes were the same and only slightly higher than fat contents in winter peas (Table 5). Overall, the mean fat content in the green and yellow peas were lower than the 5-year mean value (1.9%). The Banner cultivar had the highest fat content (1.6%) among cultivars (Table 6). Regardless of color, most other cultivars had fat contents around 1.2-1.3% (Table 6). For the eight samples of the Blaze cultivar tested, the fat content ranged from 1.1-1.3%, indicating a very consistent fat content.

Protein

Protein content of dry pea harvested in 2022 ranged from 21.0 to 26.5% with a mean of 23.4% (Table 4). The mean protein content of peas from 2022 was comparable to the value for peas from 2021. Furthermore, the mean protein (23.4%) was higher than the 5- and 10-year mean protein contents of 21.8 and 22.3% (Table 4). The mean protein contents of the green, yellow, and winter pea samples were 23.2, 22.6, and 24.1%, respectively (Table 5). Green pea samples had a mean protein content of 23.2% while the 5- and 10-year mean values were 22.3 and 22.5%, respectively. Yellow peas had a mean protein content (22.6%), which was higher than the 5- and 10-year mean protein contents of 21.5 and 21.8%, respectively (Table 5). Protein content of Winter peas was 24.1%, which was higher than the mean value of 21.3-23.1% for the previous four harvest years. The data supports higher protein content in recent years compared to long-term mean values. One sample of Shamrock (green) and one sample of Blaze (winter) had protein contents of 26.5 and 26.2%, respectively). However, the mean protein for Shamrock cultivar was 24.1% (Table 6). Salamanca and AAC Chrome cultivars had the highest and lowest protein contents of the yellow market classes (Table 6). This was opposite for Salamanca in 2021 where it was the cultivar with the lowest protein.

Total starch

Total starch content of dry pea ranged from 35.6 to 46.9% with a mean of 42.6% (Table 4). The mean total starch content of dry peas grown in 2022 was comparable to mean total starch in dry peas from the 2021 and 2018 harvest year (i.e., 42.9, 42.5%) and was lower than both the 5- and 10-year mean total starch values of 43.1 and 44.9%, respectively. The starch contents of the green and yellow market classes were 42.7 and 43.5%, respectively (Table 5). Green peas had a mean starch content (43.1%) that was comparable to the 5-year mean value (42.9%) but lower than the 10-year mean value (44.7%) of 41.0 and 42.0%, respectively. Green peas from 2022 had similar starch content compared to peas from the 2019 harvest years. The 5- and 10-year mean starch content for the yellow peas was lower (44.5 and 43.1%, respectively) than the mean starch content (45.6%) of yellow peas harvested in 2022. Unlike green peas, the peas from 2022 did not closely match the peas harvested in previous years. Winter peas from 2022 had a mean starch content (40.0%) that was substantially lower than winter peas from previous harvest years (Table 5).

Banner (green) and Blaze (winter) had the lowest (40.6 and 40.0%, respectively) starch content among pea samples (Table 6). The Blaze cultivar had the highest (49.6%) total starch in 2021 and suggests that production year may impact the starch content (Table 6). ND Victory and ND P140510Y* obtained from the ND pulse breeding program had high starch contents (46.7 and 46.9%, respectively) had the highest starch contents, which was comparable to Pizzaz with a starch content of 46.2% (Table 6).

The general trend for all samples supports higher protein and lower starch and fat contents in samples grown in 2022 compared to previous years. The drought conditions experienced in the summer of 2021 may have contributed to the observed effect of higher protein and lower starch contents. The same impact of weather may have contributed to similar results for the samples in 2022. Evidence of higher protein and lower starch has been documented in other commodities such as wheat. The data presented here on the 2022 samples demonstrates similar impact on pulses.

Physical parameters of dry pea (Tables 7-11)

Test weight ranged from approximately 44 to 66 lbs./Bu with a mean of 59.5 lbs./Bu. This mean value was approximately 4.5 and 4.0 lbs./Bu higher than the 5- and 10-year mean values of 63.9 and 63.5 lbs./Bu (Table 7). The mean test weight for all pea samples harvested in 2022 was lowest comparable to those from 2018 to 2021. The test weights of peas in the green and yellow market classes were 59.3 and 54.2 lbs./Bu, respectively (Table 8). These values were approximately 1 to 4 lbs./Bu lower than both the 5- and 10-year year mean values. Winter peas had the highest test weight at 63.6 lbs./Bu, which was lower than the winter peas from previous harvest years. The test weight of individual cultivars varied within their respective green and yellow market classes with few exceptions (Table 9). Banner (green) and Pizzaz (yellow) had the highest test weights in their respective market classes. The lowest test weights were 56.1 and 44.2 lbs./Bu for the NDP150412G (green) and NDP140510Y (yellow) varieties from the ND breeding program, respectively (Table 9). Among the samples of the Blaze cultivar evaluated, test weights ranged from 62.2 to 64.7 lbs./Bu.

Table 7. Physical parameters of dry pea grown in the USA, 2018-2022 plus 5- and 10-year mean values.

Physical Parameter	Year							
	2022		2021	2020	2019	2018	5-year	10-year
	Range	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Test Weight (lb/bu)	44.2-66.2	59.5 (5.9)	64.7 (1.3)	63.6 (1.9)	64.3 (1)	63.5 (1)	63.9 (0.7)	63.5 (1.0)
1000 Seed Wt (g)	107-259	182 (41)	199 (40)	233 (33.0)	224 (31)	211 (33)	214 (14)	215 (11)
Water Hydration Capacity (%)	102-126	112 (6)	100 (6)	97 (8.0)	96 (8)	103 (8)	100 (4)	101 (5)
Unhydrated Seeds (%)	0-16	1 (4)	0 (1)	2 (3)	2 (3)	1 (2)	1 (1)	2 (2)
Swelling Capacity (%)	111-183	141 (19	146 (12)	118 (12.4)	145 (13)	147 (14)	141 (13)	nd
Cooked Firmness (N/g)	13.5-36.5	22.1 (7.3)	24.0 (5.2)	24.9 (6.3)	21.0 (7)	21.0 (5)	23.0 (1.8)	nd

nd = not determined due to test not being performed for 10 years.

Table 8. Physical parameters of different market classes of dry pea grown in the USA, 2018-2022 plus 5- and 10-year mean values.

Physical Parameter	Mean (SD) of green pea					5-year	10-year
	2022	2021	2020	2019	2018	Mean (SD)	Mean (SD)
Test Weight (lb/bu)	59.3 (5.9)	64.4 (1.9)	64 (2)	64 (1)	63 (1)	63.5 (0.7)	63.1 (0.6)
1000 Seed Wt (g)	182 (45)	193 (26)	220 (31)	207 (28)	192 (28)	197 (13)	204 (12)
Water Hydration Capacity (%)	111 (8)	105 (3)	99 (7)	99 (6)	106 (8)	105 (3)	104 (4)
Unhydrated Seeds (%)	3 (6)	0 (0)	2 (2)	1 (1)	0 (1)	1 (1)	2 (2)
Swelling Capacity (%)	137 (31)	149 (12)	120 (12)	144 (10)	149 (12)	143 (13)	nd
Cooked Firmness (N/g)	24.2 (5.8)	21.4 (5.5)	21.7 (4)	18.9 (4.6)	19.8 (5)	21.0 (1.0)	nd
Physical Parameter	**Mean (SD) of yellow pea**					**5-year**	**10-year**
	2022	**2021**	**2020**	**2019**	**2018**	**Mean (SD)**	**Mean (SD)**
Test Weight (lb/bu)	54.2 (5.9)	63 (2)	64 (1)	63 (1)	63 (2)	63.4 (0.5)	63 (1)
1000 Seed Wt (g)	221 (30)	244 (28)	222 (31)	214 (30)	231 (27)	227 (12)	224 (11)
Water Hydration Capacity (%)	108 (5)	93 (7)	102 (8)	102 (5)	95 (6)	99 (4)	100 (5)
Unhydrated Seeds (%)	0 (0)	2 (3)	0 (2)	1 (1)	2 (4)	1 (0)	2 (2)
Swelling Capacity (%)	143 (20)	116 (12)	146 (14)	150 (9)	135 (16)	139 (14)	nd
Cooked Firmness (N/g)	28.3 (7.1)	27.2 (6.6)	22.0 (7.1)	21.7 (5)	25 (6)	24.4 (2.3)	nd
Physical Parameter	**Mean (SD) of winter pea**					**5-year**	**10-year**
	2022	**2021**	**2020**	**2019**	**2018**	**Mean (SD)**	**Mean (SD)**
Test Weight (lb/bu)	63.6 (0.9)	65.0 (0.7)	65 (0.4)	65 (0)	**	nd	nd
1000 Seed Wt (g)	152 (12)	156 (14)	175 (12)	154 (39)		nd	nd
Water Hydration Capacity (%)	115 (2)	103 (5)	96 (5)	85 (8)	**	nd	nd
Unhydrated Seeds (%)	1 (1)	0 (0)	1 (1)	7 (8)	**	nd	nd
Swelling Capacity (%)	141 (6)	156 (7)	119 (8)	131 (3)			
Cooked Firmness (N/g)	16.0 (2.1)	24.3 (3.7)	21.6 (1.6)	24.6 (8.3)	**	nd	nd

*composition is on an "as is" basis; **not previously reported; nd = not determined due to test not being performed for 5 or 10 years.

Table 9. Mean physical parameters of USA dry pea cultivars grown in 2022.

Market Class	Cultivar	Test Weight (lb/bu)	1000 Seed Weight (g)	Water Hydration Capacity (%)	Unhydrated Seeds (%)	Swelling Capacity (%)	Cooked Firmness (N/g)
Green	Banner*	66.2	187	106	0	132	20.5
	Ginny 2*	64.0	107	107	16	112	21.0
	ND Victory*	56.6	180	102	0	120	35.1
	NDP150412G*	56.1	202	111	2	111	24.3
	Shamrock	56.4	208	119	1	175	22.1
Yellow	AAC Chrome*	57.9	231	109	0	133	23.9
	AAC Julius*	49.9	198	111	0	124	23.3
	NDP140510Y*	44.2	197	103	0	170	36.5
	NDP150231Y*	57.7	190	102	0	137	34.4
	Pizzaz*	59.0	259	110	0	129	19.1
	Salamanca*	56.4	253	114	0	167	32.3
Winter	Blaze	63.6	152	115	1	141	16.0

*Only one sample of cultivar tested

The range and mean **1000 seed weight** of dry peas grown in 2022 were 107-259 g and 182 g, respectively (Table 7). The mean value (182 g) was lower than the 5- and 10-year mean 1000 seed weight of peas. This supports lighter seeds for the peas harvested in 2022. Peas of the green market class had a mean 1000 seed weight of 193 g, which is significantly lower than the 5- and 10-year mean value 1000 seed weight of 197 and 204 g, respectively (Table 8). Peas of the yellow market class had a mean 1000 seed weight of 221 g, which is slightly lower than the 5- and 10-year mean 1000 seed weight (Table 8). Winter pea samples harvested in 2022 had lower 1000 seed weight compared to peas harvested in 2020 but the was comparable to the 1000 seed weight from peas grown in 2019 and 2021.

The individual cultivars (Table 9) varied extensively in 1000 seed weight, where cultivars in the green market class varied (107 to 208 g) more than cultivars in the yellow market class (190 to 259 g). Shamrock (208 g) and Pizzaz (259 g) and Ginny 2 (107 g) and NDP150231Y (190 g) had the highest and lowest 1000 seed weight in the green and yellow market class, respectively (Table 9). The winter peas had mean 1000 seed weight was 152 g with a range 131 to 172 g. However, the winter peas tended to have similar 1000 seed weights to winter peas from 2019 and 2021 harvest years. The test weight and 1000 seed weight support that the peas from 2022 tended to be smaller than the peas from previous crop years, with only a few exceptions.

The water absorption or hydration properties of peas are important for understanding how peas will hydrate and increase in size and weight. We can measure hydration properties by measuring water hydration capacity, percentage of unhydrated seeds and swelling capacity.

Water hydration capacity of dry peas ranged from 102 to 126%, with a mean of 112% (Table 7). The 2022 mean value is slightly higher than the 5- and 10-year mean water hydration capacity of 100 and 101%, respectively. Peas from the 2022 harvest year had slightly higher water hydration capacity compared to peas from 2018-2021. The mean water hydration capacity of peas in the green market class was 3 percentage points higher than the mean hydration capacity of the yellow but was 4 percentage points lower than the water hydration capacity of the winter peas (Table 8).

The mean water hydration capacity of the green peas in 2022 was slightly higher than the 5- and 10-year mean water hydration capacities (Table 8). The yellow peas from 2022 had a mean water hydration capacity that was higher than the 5- and 10-year mean water hydration capacities. In the green market class, ND Victory and Shamrock had the lowest (102%) and highest (119%) water hydration capacities, respectively. In 2020 and 2021, Shamrock also had the highest water hydration capacity. The water hydration capacity ranged from 102% in sample NDP150231Y to 114% in the Salamanca cultivar (Table 9). The Salamanca cultivar also had the highest water hydration capacity in 2021. The water hydration capacity ranged from 112-120% among the winter pea samples.

Unhydrated seed percentage ranged from 0-16% with a mean of 1%, which is comparable to the 5- and 10-year mean unhydrated seed percentage (Table 7). Green and yellow peas had unhydrated seed values of 3 and 0%, respectively (Table 8). Winter peas had 1% unhydrated seed rate. The yellow pea samples had lower unhydrated seed percentages as the 5- and 10-year mean value (Table 8). Most of the green pea cultivars had unhydrated seed rates of 0-2%; however, a 16% unhydrated seed rate was found in the Ginny 2 cultivar and thus contributed to the higher mean unhydrated percentage (Table 9). The yellow cultivars all had 0% unhydrated seed counts. The Blaze cultivar in the winter peas ranged from 0-3% unhydrated seed. Overall, the low numbers (0-3%) suggest that no issues should occur during rehydration of the peas.

The **swelling capacity** is the amount of swelling that occurred during re-hydration of the dry pea. The swelling capacity of all peas ranged from 111% to 183% with a mean value of 141% (Table 7). The mean swelling capacity for peas from the 2022 harvest was the same as the 5-year mean swelling capacity (Table 7). The mean swelling capacity was higher than the value reported for the 2020 samples but comparable to samples from previous harvest years. Unlike 2018 and 2021, the swelling capacity of green peas from 2022 was lower than the mean swelling capacity of the yellow peas (Table 8). The yellow peas had essentially the same swelling capacity as the winter peas. The green and yellow peas had swelling capacities that were comparable to their respective 5-year mean swelling capacities. Variability in the swelling capacity among cultivars was observed (Table 9). Ginny2 (green) and AAC Julius (yellow) had the least swelling capacity among commercial cultivars. Shamrock (green) and Salamanca (yellow) had the highest swelling capacities among the cultivars tested (Table 9). The swelling capacity among Blaze cultivar ranged from 131 to 172%.

The **cooked firmness** values for all peas combined were lower in the peas from 2022 compared to the 5-year mean cooked firmness. The cooked firmness for all peas ranged from 13.5 to 36.5 N/g with a mean value of 22.1 N/g (Table 7). The cooked firmness of peas was different between market classes (Table 8). The winter peas had lower firmness values than those of the green and yellow peas. In contrast to the overall cooked firmness, the mean cooked firmness of green and yellow peas obtained in 2022 were higher than the 5-year mean value (Table 8). The winter peas had mean cooked firmness well below the firmness of cooked winter peas from previous years. Among the green cultivars, Banner had the lowest cooking firmness (20.5 N/g) while Shamrock (22.1 N/g) was the firmest among commercial cultivars (Table 9). Pizzaz and Salamanca had the lowest (19.1 N/g) and highest (32.3 N/g) cooked firmness, respectively (Table 9). The winter peas had cooked firmness values that ranged from 13.8 to 20.4 N/g.

Color quality was measured using an L*, a*, and b* and from these values a color difference can be determined on peas before and after soaking. **Color quality** for the pea samples in 2022 indicated that the peas had L* values that were higher than the 5- and 10-year mean L* values (Table 10). The mean L* value of yellow peas was higher than the 5-year mean L* but the same as the 10-year L* value. The L* values for green peas in 2022 matched the L* for peas from 2020 while yellow L* mean value matched the L* values of peas from 2020

Table 10. Color quality of dry pea grown in the USA before and after soaking in water 16 hours, 2019-2022 plus 5- and 10-year mean values.

Color Scale*	Before Soaking						After Soaking					
Mean (SD) of green pea	2022	2021	2020	2019	5-Year	10-Year	2022	2021	2020	2019	5-Year	10-Year
L (lightness)	58.45 (2.23)	57.34 (2.63)	58.82 (2.75)	48.99 (3.35)	53.90 (3.65)	57.18 (5.31)	52.55 (2.15)	53.41 (2.63)	54.69 (3.26)	50.42 (4.09)	50.31 (3.46)	52.43 (4.42)
a (red-green)	-1.97 (0.56)	-2.21 (1.25)	-1.35 (1.97)	-2.46 (0.92)	-1.84 (0.47)	-1.73 (1.55)	-7.40 (0.59)	-7.43 (1.67)	-6.47 (3.45)	-6.28 (1.20)	-6.32 (0.70)	-7.71 (2.73)
b (yellow-blue)	10.16 (0.68)	10.14 (1.28)	9.84 (1.51)	9.23 (0.92)	11.69 (2.43)	11.96 (2.61)	17.73 (1.98)	16.11 (2.57)	17.50 (3.24)	12.63 (2.25)	20.68 (6.64)	22.41 (6.54)
Color Difference	11.10 (1.98)	9.04 (2.18)	10.78 (1.93)	6.44 (3.05)	11.62 (3.79)	nd						
Mean (SD) of yellow pea												
Color Scale	Before Soaking						After Soaking					
	2022	2021	2020	2019	5-Year	10-Year	2022	2021	2020	2019	5-Year	10-Year
L (lightness)	63.57 (1.34)	63.30 (1.01)	63.42 (2.64)	56.69 (2.98)	60.18 (2.70)	63.13 (5.04)	62.54 (1.13)	63.91 (0.64)	65.03 (1.47)	60.74 (2.03)	62.04 (2.03)	65.45 (4.86)
a (red-green)	4.80 (0.95)	4.29 (1.16)	4.99 (0.68)	4.97 (0.71)	5.60 (1.07)	5.80 (1.11)	4.74 (0.65)	5.16 (1.16)	5.50 (0.75)	3.89 (1.20)	6.11 (1.92)	6.11 (1.89)
b (yellow-blue)	15.53 (0.33)	11.73 (2.32)	14.61 (0.95)	14.48 (1.75)	16.09 (3.23)	17.03 (3.52)	29.76 (0.62)	22.06 (2.57)	28.89 (1.41)	21.15 (3.19)	29.60 (7.33)	31.58 (7.72)
Color Difference	14.29 (0.50)	13.53 (2.18)	14.63 (2.06)	8.46 (2.52)	14.88 (3.88)	nd						

*color scale: L (lightness) axis – 0 is black and 100 is white; a (red-green) axis – positive values are red, negative values are green, and zero is neutral; and b (yellow-blue) axis – positive values are yellow, negative values are blue, and zero is neutral. Color difference = change in value before soaking and after soaking. nd = not determined due to test not being performed for 10 years.

and 2021. Overall, the high L* indicates that the peas from the 2022 crop year were lighter in color than those from the 2019 harvest year but comparable to the long term (10 year) seed lightness. The negative value for red-green (i.e., a* value) value in 2022 indicates slightly less green color to samples from 2021 and 2019 (Table 10). The a* value for green peas from 2022 were comparable to the 5- and 10-year mean a* values indicating that the peas had similar greenness to pea over the long term. The b* value was most comparable to the green peas from 2021 but was significantly lower than the 5- and 10-year mean b* values. The lower b* value indicates a bluer color. The lower (more negative) a* combined with a lower b* value indicates that the pulses would be a dark green color. Therefore, the green peas in 2022 appear greener in color compared to peas with a long term mean a* and b* present in Table 10 but were slightly less green than the peas from 2021.

For the yellow pea market class, the 2022 crop had lightness values comparable to previous pea samples except for the pea samples from 2019. Overall, the L* values of the 2022 pea samples matched the 10-year mean L* value and was higher than the 5-year mean L* value, indicating that the peas in 2022 were slightly lighter than samples from previous years but comparable to the long-term (10 year) lightness value. The a* value of the yellow peas was on the red side of the scale indicating the lack of a green appearance. The yellow pea in 2022 had a* values that were like the a* values in peas from 2019 and 2020. The a* values for yellow peas from 2022 were less than the 5- and 10-year mean a* (Table 10). Similarly, the b* values for peas in 2022 were less than the 5- and 10-year mean b* values. However, the b* value for the peas from 2022 was slightly higher than for peas from 2019 and 2020 and substantially higher than the b* value of peas from 2021. This indicates that the yellowness of peas from 2022 was greater than that of peas from 2021s. A higher b* values combined with an a* value on the red part of the scale indicates that the samples would be light yellow in color. A lower a* combined with a lower b* values indicates that the pulses would be a darker yellow to light brown color. Therefore, the yellow peas in 2022 appeared yellow to dark yellow in color compared to peas from 2021. The color of the dry peas changed after the soaking process. The change in color as measured by color difference was greater for green peas from 2022 compared to the peas from previous crop years (Table 10). The green peas became darker (lower L*) while the a* value became more negative (i.e., greener), but more yellow (i.e., increased b* value). This trend was like previous crop years. In 2022, lightness decreased slightly after soaking of the yellow peas. However, these changes were opposite compared to the 5- and 10-year mean where values increase after soaking (Table 10). In addition, soaking caused a minimal change in greenness (i.e., similar a* value pre- and post-soak) and an increased yellowness (i.e., higher b* value) of the yellow peas. This suggests that the peas appeared more yellow after soaking (Table 10) but to a lesser degree compared to peas that make up the 5- and 10-year mean color values. The color difference test indicates a general change in color after soaking or other process. The green market class underwent less color change during soaking than did the yellow peas (Table 10). Although color difference is a general indicator of change, visual observations support a darkening of the green color in the green pea market class and an increase in yellowness after the soaking process in the yellow peas. The color difference values observed in 2022 were more than in samples from previous years except 2020. Less color differences were observed in both green and yellow pea samples compared to the 5-year mean color difference value.

Table 11. Color quality of USA dry pea cultivars before and after soaking, 2022.

Market Class	Cultivar	Before Soaking L	Before Soaking a	Before Soaking b	After Soaking L	After Soaking a	After Soaking b	Color Difference
Green	Banner*	57.67	-2.65	10.11	53.77	-7.12	14.70	7.56
	Ginny 2*	61.19	-1.50	9.06	55.95	-7.21	15.83	10.30
	ND Victory*	58.89	-2.01	9.82	52.40	-7.69	18.34	12.13
	NDP150412G*	60.74	-1.15	10.46	52.52	-6.71	19.02	13.11
	Shamrock	56.10	-2.27	10.75	50.32	-7.84	19.26	11.74
Yellow	AAC Chrome*	63.59	5.15	15.47	62.31	5.00	29.20	13.79
	AAC Julius*	62.41	6.08	15.84	61.19	5.51	29.43	13.65
	NDP140510Y*	64.66	4.26	15.81	63.59	3.99	30.27	14.51
	NDP150231Y*	61.92	3.28	15.48	61.26	4.08	30.26	14.82
	Pizzaz*	63.34	5.20	15.63	63.21	5.34	30.40	14.77
	Salamanca*	65.50	4.82	14.94	63.68	4.51	29.00	14.18
Winter	Blaze	60.59	2.05	13.32	61.61	2.54	26.14	12.90

(Mean Color Values**)

*Only one sample of cultivar tested; **color scale: L (lightness) axis – 0 is black and 100 is white; a (red-green) axis – positive values are red, negative values are green, and zero is neutral; and b (yellow-blue) axis – positive values are yellow, negative values are blue, and zero is neutral.

The Shamrock cultivar from 2022 had the lowest L* values (Table 11). Banner had the most negative a* value and one of the lowest b* values, giving it a dark green appearance. Ginny 2 had the highest L*, and a* values, giving it a light green appearance. The L* value decreased in all cultivars upon soaking. The a* values for all cultivars became more negative (i.e., greener) and more yellow (i.e., increased b* value). This combination of changes resulted in peas that appeared greener. Of the commercial cultivars, the greatest color difference was observed in the Shamrock cultivar while Banner underwent the least color change.

The cultivars of the yellow peas had L* values between 61.92 and 65.50, with Salamanca being the lightest (Table 11). Salamanca retained the lightest color after soaking while AAC Julius became the darkest (i.e., lowest L*). Of the commercial cultivars, Salamanca had the lowest redness (a*) and yellowness (b*) scores while the highest were observed for the AAC Julius cultivar (Table 11). After soaking, Salamanca and AAC Julius cultivars also had the lowest and highest redness values. After soaking, Pizzaz had the highest yellowness values while Salamanca had the lowest. These were the same outcomes observed in 2021. Aside from an experimental cultivar, the greatest color difference was observed in the Pizzaz cultivar. The substantial increase in yellowness during soaking likely contributed to the greatest color difference for Pizzaz. AAC Julius had the least color change during soaking.

In 2022, Blaze was the only winter pea cultivar evaluated (Table 11). Compared to samples from 2021, samples from 2022 had lower L*, a* and b* values. This indicates that the samples (pre-soaked and soaked) from 2022 had color that was darker, less red, and less yellow compared

to Blaze from 2021. However, color difference values were more pronounced in the Blaze cultivar from 2021 (15.10) compared to the color differences in the Blaze cultivar from 2022 (12.90).

Starch Properties (Tables 12-14)

The peas from 2022 had mean peak viscosity, hot and cold paste viscosities, and setback values that were significantly lower than 5- and 10-year mean values for these same parameters (Table 12). Mean peak time was slightly more than the 5- and 10-year mean peak time values. This indicates that the samples begin to form a paste later than most samples from the 10-year period. The pasting temperature of the samples ranged from 75.9-84.3 °C, with a mean of 80.6°C. The mean value is nearly 3 °C higher than the 5-year mean pasting temperature. However, the data for peas overall was likely impacted by the data obtained from the winter peas. The starch characteristics were similar between the green and yellow pea market classes but different from that obtained for the winter peas.

Table 12. Starch characteristics of dry peas grown in the USA, 2018-2022 plus 5- and 10-year mean values.

Starch Characteristic	2022 Range	2022 Mean (SD)	2021 Mean (SD)	2020 Mean (SD)	2019 Mean (SD)	2018 Mean (SD)	5-Year Mean (SD)	10-Year Mean (SD)
Peak Viscosity (RVU)	69-155	114 (23)	126 (17)	134 (5)	146 (15)	139 (15)	140 (5)	137 (8)
Hot Paste Viscosity (RVU)	63-142	105 (20)	118 (15)	124 (14)	131 (12)	129 (13)	128 (3)	126 (6)
Breakdown (RVU)	2-17	9 (5)	9 (5)	10 (5)	16 (6)	10 (5)	11 (3)	11 (4)
Cold Paste Viscosity (RVU)	118-241	176 (33)	204 (38)	229 (38)	233 (30)	235 (33)	233 (3)	229 (15)
Setback (RVU)	52-98	71 (15)	86 (24)	105 (26)	104 (22)	105 (22)	105 (1)	103 (10)
Peak Time (Minute)	4.87-7.00	5.94 (0.89)	5.37 (0.31)	5.29 (0.41)	5.11 (0.40)	5.00 (0)	5.25 (0.09)	5.88 (1.44)
Pasting Temperature (°C)	75.9-84.3	80.6 (2.8)	79.9 (1.8)	77.7 (1.8)	76.4 (1.3)	77.6 (2.1)	77.3 (0.6)	nd
RVA Starch Gel Firmness (g)	161-380	243 (73)	**	**	**	**	nd	nd

**not previously reported; nd = not determined due to test not being performed for 5 or 10 years.

The pasting values for the green and yellow peas were higher than pasting data for the winter peas. For example, mean peak viscosities of 131 and 127 RVU were recorded for the green and yellow market classes, respectively, while a value of 91 RVU was observed for winter peas (Table 13). For the green and yellow market class, pasting properties followed the same trend where the 5- and 10-year mean viscosity were substantially higher than the values for pea from 2022. A similar trend of lower pasting values can be made for the winter pea samples comparable to winter peas from 2019-2021 (Table 13). However, the pasting temperature was about 2 to 6°C higher for pea samples in 2022 compared to the peas from 2019-2021. Collectively, the data indicates that significant changes in the starch, whether total starch content or alterations in the starch structure, may be the basis for the observation and that the environmental conditions likely impacted the starch during the growing season. New in 2022 was the RVA gel firmness measure. The gel firmness varied significantly (161-380 g) where winter pea produced a gel that was the least firm while yellow pea samples had the highest (290 g) mean RVA gel firmness (Tables 12 and 13).

Table 13. Starch characteristic of different market classes of dry peas grown in the USA, 2018-2022 plus 5- and 10-year mean values.

Physical Parameter	Mean (SD) of green pea					5-year	10-year
	2022	2021	2020	2019	2018	Mean (SD)	Mean (SD)
Peak Viscosity (RVU)	131 (13)	127 (23)	138 (16)	143 (17)	139 (15)	137 (6)	137 (9)
Hot Paste Viscosity (RVU)	118 (13)	120 (20)	127 (13)	127 (14)	128 (13)	126 (3)	125 (6)
Breakdown (RVU)	13 (4)	6 (5)	11 (3)	16 (6)	11 (5)	11 (3)	11 (6)
Cold Paste Viscosity (RVU)	194 (28)	209 (53)	239 (40)	220 (32)	228 (38)	226 (12)	229 (15)
Setback (RVU)	75 (17)	89 (35)	112 (29)	93 (22)	101 (27)	99 (9)	103 (11)
Peak Time (Minute)	5.26 (0.21)	5.48 (0.40)	5.29 (0.30)	5.17 (0.35)	5.00 (1)	5.25 (0.18)	6.02 (1.37)
Pasting Temperature (°C)	79.4 (2.2)	80.4 (1.6)	78.3 (1.6)	76.8 (1.3)	78 (2)	78.0 (1.7)	nd
RVA Gel Firmness (g)	249 (89)	**	**	**	**	nd	nd
Starch Characteristics	**Mean (SD) of yellow pea**					**5-year**	**10-year**
	2022	**2021**	**2020**	**2019**	**2018**	**Mean (SD)**	**Mean (SD)**
Peak Viscosity (RVU)	127 (16)	130 (13)	132 (15)	148 (14)	140 (14)	138 (7)	138 (7)
Hot Paste Viscosity (RVU)	117 (13)	120 (12)	122 (13)	133 (10)	131 (12)	127 (6)	127 (5)
Breakdown (RVU)	11 (6)	9 (4)	13 (5)	16 (6)	9 (5)	11 (3)	12 (3)
Cold Paste Viscosity (RVU)	196 (28)	205 (30)	223 (34)	240 (27)	238 (29)	228 (14)	228 (15)
Setback (RVU)	79 (15)	84 (19)	101 (23)	110 (20)	108 (19)	101 (10)	101 (11)
Peak Time (Minute)	5.22 (0.23)	5.37 (0.14)	5.29 (0.48)	5.17 (0.35)	5 (1)	5.20 (0.16)	5.90 (1.42)
Pasting Temperature (°C)	78.1 (1.6)	79.9 (0.7)	77.2 (1.7)	76.2 (1.3)	77 (2)	77.7 (1.4)	nd
RVA Gel Firmness (g)	290 (71)	**	**	**	**	nd	nd
Physical Parameter	**Mean (SD) of winter pea**					**5-year**	**10-year**
	2022	**2021**	**2020**	**2019**	**2018**	**Mean (SD)**	**Mean (SD)**
Peak Viscosity (RVU)	91 (13)	121 (14)	126 (11)	134 (19)	**	nd	nd
Hot Paste Viscosity (RVU)	85 (13)	111 (12)	113 (12)	118 (8)	**	nd	nd
Breakdown (RVU)	6 (2)	10 (6)	13 (2)	16 (13)	**	nd	nd
Cold Paste Viscosity (RVU)	147 (19)	197 (28)	216 (33)	209(35)	**	nd	nd
Setback (RVU)	62 (7)	86 (19)	103 (22)	92 (28)	**	nd	nd
Peak Time (Minute)	6.98 (0.05)	5.25 (0.33)	5.18 (0.17)	5.58 (0.91)	**	nd	nd
Pasting Temperature (°C)	83.4 (0.7)	80.9 (2.2)	78.8 (1.4)	77.5 (1.5)	**	nd	nd
RVA Gel Firmness (g)	203 (36)	**	**	**	**	nd	nd

**not previously reported; nd = not determined due to test not being performed for 5 or 10 years.

Within each market class, variability in starch characteristics was observed among cultivars. In the green pea, the Shamrock cultivar had the highest peak, hot paste, and cold paste viscosities (Table 14). In contrast, the Banner commercial cultivar had the lowest peak, and hot paste viscosities. AAC Julius had the highest peak, hot paste, and cold paste viscosities among yellow cultivars. The lowest peak, hot paste, and cold paste viscosities in the yellow market class were observed in the Salamanca cultivar (Table 14). The Blaze winter pea had lowest peak, hot paste, and cold paste viscosities compared to cultivars from the green and yellow pea categories. However, type C pasting profile was demonstrated by all of the cultivars tested. This curve is represented by a minimally definable pasting peak, a small breakdown in viscosity and high final peak viscosity. The breakdown ranged from 2 to 17 RVU, which represents little breakdown of the starch paste. The setback values ranged from 61 to 97 RVU, which represents a significant setback for some of the samples. Collectively, these properties of the starch are ideal for glass noodle production.

Table 14. Mean starch characteristics of dry pea cultivars grown in the USA in 2022.

Market Class	Cultivar	Peak Viscosity (RVU)	Hot Paste Viscosity (RVU)	Breakdown (RVU)	Cold Paste Viscosity (RVU)	Setback (RVU)	Peak Time (Min)	Pasting Temperature (°C)	RVA Gel Firmness (g)
Green	Banner*	132	116	16	204	88	5.40	79.9	167
	Ginny 2*	136	120	16	203	83	5.37	82.3	181
	ND Victory*	121	104	17	169	65	4.93	76.8	230
	NDP150412G*	120	109	11	176	67	5.07	77.5	340
	Shamrock	139	130	9	205	75	5.40	79.9	288
Yellow	AAC Chrome*	135	125	11	206	82	5.33	77.5	280
	AAC Julius*	148	132	15	229	97	5.33	79.1	380
	NDP140510Y*	103	102	2	168	66	5.33	76.7	289
	NDP150231Y*	138	122	16	218	96	4.87	75.9	326
	Pizzaz*	126	121	4	193	72	5.47	79.2	165
	Salamanca*	115	99	15	160	61	5.00	80.0	299
Winter	Blaze	91	85	6	147	62	6.98	83.4	203

*Only one sample of cultivar tested

Functionality Properties (Tables 15-17)

Functionality property evaluation is new in 2022. These tests include emulsion activity and stability, foaming capacity and stability, water holding capacity and oil holding capacity. The emulsion activity and stability for all samples ranged from 57-60% and 55-62% (Table 15). However, the peas from the various market classes had the same emulsion activity and stability (Table 16). Furthermore, no one cultivar had emulsion activity and stability values that were substantially different from others. In contrast to emulsion activity, foaming capacity varied to a greater extent (173-267%). Differences in foaming capacity among different classes of peas were observed (Table 16), however, less variability was observed in the foam stability of the peas from different market classes. In contrast, at the cultivar/variety level differences in foaming capacity and stability were evident (Table 17). Groupings among the cultivars were observed for the water holding capacity where values grouped around 1.24-1.28 or 1.43 g/g. In oil holding capacity, only the winter pea (Blaze) was substantially different (i.e., higher) from the other samples.

Table 15. Functional properties of dry pea grown in the USA, 2022.

Functional Properties	Year 2022 Range	Mean (SD)
Emulsion Activity (%)	57-60	59 (1)
Emulsion Stability (%)	55-62	58 (2)
Foaming Capacity (%)	173-267	215 (27)
Foam Stability (%)	45-83	62 (10)
Water Holding Capacity (g/g)	1.08-1.45	1.28 (0.12)
Oil Holding Capacity (g/g)	0.11-0.87	0.37 (0.27)

Table 16. Functional properties of different market classes of dry pea grown in the USA, 2022.

Functional Properties	Mean (SD) Green	Yellow	Winter
Emulsion Activity (%)	59 (1)	59 (1)	58 (1)
Emulsion Stability (%)	58 (1)	59 (1)	58 (3)
Foaming Capacity (%)	221 (33)	208 (25)	215 (26)
Foam Stability (%)	58 (9)	67 (14)	63 (8)
Water Holding Capacity (g/g)	1.34 (0.14)	1.31 (0.10)	1.22 (0.11)
Oil Holding Capacity (g/g)	0.17 (0.04)	0.16 (0.03)	0.68 (0.15)

Table 17. Mean functional properties of dry pea cultivars grown in the USA, 2022.

Market Class	Cultivar	Emulsion Activity (%)	Emulsion Stability (%)	Foaming Capacity (%)	Foam Stability (%)	Water Holding Capacity (g/g)	Oil Holding Capacity (g/g)
Green	Banner*	58	59	183	68	1.24	0.23
	Ginny 2*	58	59	190	56	1.44	0.15
	ND Victory*	60	56	263	45	1.43	0.22
	NDP150412G*	57	57	257	55	1.45	0.17
	Shamrock	60	60	217	63	1.23	0.13
Yellow	AAC Chrome*	57	61	193	83	1.16	0.16
	AAC Julius*	60	59	223	52	1.43	0.19
	NDP140510Y*	60	56	207	74	1.42	0.11
	NDP150231Y*	57	55	247	66	1.31	0.15
	Pizzaz*	59	62	173	48	1.28	0.15
	Salamanca*	59	59	202	75	1.28	0.17
Winter	Blaze	58	58	215	63	1.22	0.68

*Only one sample of cultivar tested

Lentil Quality Results

Sample distribution

A total of 18 lentil samples were collected from Montana and Washington between August 2022 to January 2023. Samples were delivered to SDSU between January 2023 and April 2023. Growing location, number of samples, market class, and genotype details of these dry pea samples are provided in Table 18. Pardina (12) and Merrit (5) account for the majority of the lentil samples.

Table 18. Description of lentils used in the 2022 pulse quality survey.

State	No. of Samples	Market Class	Cultivars
Montana	1	Green	Avondale
Washington	17	Green	Merrit
		Spanish Brown	Pardina

Proximate composition of lentils (Tables 19-21)

Moisture

The moisture content of lentils ranged from 7.7 to 9.7% in 2022 (Table 19). The mean moisture content (8.5%) was slightly higher than the 5- and 10-year mean moisture content of 8.0 and 8.3%, respectively and was most similar to the mean moisture value of lentils from 2018, but lower than lentils from 2019. Overall, all samples evaluated had moisture contents below the 13-14% recommended general storability. The moisture contents of the different market classes were between 8.5 and 8.6% (Table 20). The green lentils had a mean moisture content of 8.6% while Spanish brown lentils had moisture contents of 8.5%. No red lentils were evaluated in 2022. The green lentils from 2022 had lower moisture contents than the 5- and 10-year mean moisture contents of 8.9%. The mean moisture content of green lentils from 2022 was similar to the green lentils from 2020 and 2021. Spanish brown lentils had a mean moisture content that was comparable to the 5-year mean value, but higher than the lentils from 2018, 2020, and 2021, but lower than Spanish brown lentils from 2019. The highest moisture contents were observed in the Merrit (8.8%) cultivar (i.e., green lentil) while the Avondale (7.8%) cultivar (i.e., green lentil) had the lowest moisture content (Table 21). In 2022, the 12 separate Pardina samples had a range of moisture content from 7.7 to 9.7% whereas the five Merritt samples ranged from 8.1 to 9.2%.

Ash

The ash content of lentils ranged from 2.5 to 3.2% with a mean of 2.8% (Table 19). The mean ash content of lentils grown in 2022 was only slightly higher than the 5- and 10-year mean ash content of 2.6%. Ash content is a general indicator of minerals present. The mean ash contents of the green and Spanish brown market classes were 2.9 and 2.8%, respectively (Table 20). The Merrit cultivar had the highest (2.9%) mean ash content among cultivars tested (Table 21). However, the mean ash contents of the other cultivars were 2.8%, thus the samples evaluated in 2022 had virtually the same ash content.

Fat

The fat content of lentils ranged from 0.9 to 1.2% with a mean of 1.0% (Table 19). The fat content was measured in 2017 for the first time; thus, no 10-year mean value is available. However, the fat content of lentils from the 2022 harvest year was significantly lower than the 5-year mean fat content of 1.6%. The mean fat content of lentils from 2022 was similar to fat content in lentils from 2021 (0.9%), 2019 (1.1%) and 2020 (1.3%). Literature reports indicate that lentils have fat contents between 1 and 3%; therefore, the fat content of most of the lentils grown in 2022 falls at the lower end of the range reported by others. No difference in fat percentages were observed between the different market classes (Table 20). No difference in the mean fat contents was observed among the cultivars (Table 21). However, small variation (0.9-1.2%) was observed among the 12 samples of Pardina evaluated in 2022. This data supports the consistent low fat content of lentils.

Table 19. Proximate composition of lentils grown in the USA, 2018-2022 plus 5- and 10-year mean values.

Proximate Composition (%)*	2022 Range	2022 Mean (SD)	Mean 2021 Mean (SD)	2020 Mean (SD)	2019 Mean (SD)	2018 Mean (SD)	5-year Mean (SD)	10-year Mean (SD)
Moisture	7.7-9.7	8.5 (0.6)	8.0 (0.9)	8.2 (1.2)	9.8 (1.6)	8.4 (1.1)	8.0 (0.8)	8.3 (1.6)
Ash	2.5-3.2	2.8 (0.2)	2.7 (0.3)	2.6 (0.4)	2.4 (0.3)	2.6 (0.3)	2.6 (0.2)	2.6 (0.1)
Fat	0.9-1.2	1.0 (0.1)	0.9 (0.1)	1.3 (0.5)	1.1 (0.3)	2.6 (0.8)	1.6 (0.1)	nd
Protein	22.6-27.7	24.9 (1.4)	24.5 (1.3)	24.8 (1.5)	24.3 (1.5)	24.4 (1.9)	24.3 (1.24)	23.8 (1.0)
Total Starch	37.8-43.4	40.9 (1.7)	43.0 (2.0)	44.4 (2.8)	42.8 (1.6)	44.0 (2.9)	43.6 (1.40)	44.9 (4.6)

*composition is on an "as is" basis; nd = not determined due to test not being performed for 10 years.

Table 20. Proximate composition of different market classes of lentils grown in the USA, 2018-2022 plus 5- and 10-year mean values.

Market Class	Proximate Composition (%)	Mean (SD) 2022	2021	2020	2019	2018	5-Year Mean (SD)	10-Year Mean (SD)
Green	Moisture	8.6 (0.6)	8.1 (0.9)	8.5 (1.2)	10.3 (1.8)	8.8 (1.1)	8.9 (0.8)	8.9 (1.6)
	Ash	2.9 (0.1)	2.7 (0.3)	2.5 (0.5)	2.4 (0.2)	2.6 (0.4)	2.5 (0.1)	2.5 (0.2)
	Fat	1.0 (0.1)	0.9 (0.1)	1.3 (0.5)	1.1 (0.4)	2.8 (0.8)	1.6 (0.8)	nd
	Protein	25.7 (1.3)	24.9 (1.3)	24.5 (1.6)	24.8 (1.5)	24.2 (2.0)	24.3 (0.7)	23.7 (1.2)
	Total Starch	39.0 (1.2)	42.0 (1.3)	44.7 (2.9)	42.1 (1.4)	44.1 (3.4)	43.4 (1.2)	45.0 (4.9)
Red	Moisture	*	10.6 (0)	7.9 (1.2)	8.8 (1.0)	7.6 (1.1)	8.7 (1.2)	8.6 (1.6)
	Ash	*	2.5 (0)	2.7 (0.3)	2.4 (0.3)	2.8 (0.1)	2.6 (0.2)	2.7 (0.2)
	Fat	*	0.8 (0)	1.3 (0.4)	1.2 (0.3)	2.1 (0.3)	1.5 (0.6)	nd
	Protein	*	25.1 (0)	26.3 (0.9)	24.7 (0.8)	26.0 (0.6)	25.3 (0.8)	24.7 (1.1)
	Total Starch	*	39.2 (0)	43.6 (4.1)	42.8 (0.7)	42.8 (1.2)	42.5 (1.9)	44.3 (4.7)
Spanish Brown	Moisture	8.5 (0.6)	7.6 (0.4)	7.5 (0.8)	9.8 (1.2)	7.8 (0.8)	8.2 (0.9)	nd
	Ash	2.8 (0.2)	2.8 (0.4)	2.6 (0.1)	2.4 (0.3)	2.6 (0.2)	2.6 (0.1)	nd
	Fat	1.0 (0.1)	0.9 (0.1)	1.6 (0.4)	1.1 (0.2)	2.0 (0.5)	1.6 (0.6)	nd
	Protein	24.4 (1.2)	23.9 (1.3)	24.9 (0.9)	23.5 (1.2)	24.3 (1.4)	24.0 (0.6)	nd
	Total Starch	41.8 (1.0)	44.6 (1.5)	43.9 (1.8)	43.9 (1.5)	44.4 (1.2)	44.1 (0.3)	nd

* no red lentils evaluated in 2022; nd = not determined due to test not being performed for 10 years.

Protein

Table 21. Mean proximate composition of lentil cultivars grown in the USA in 2022.

Market Class	Cultivar	Concentration (%) Moisture	Ash	Fat	Protein	Starch
Green	Avondale*	7.8	2.8	1.0	24.5	40.7
	Merrit	8.8	2.9	1.1	26.0	38.7
Spanish Brown	Pardina	8.5	2.8	1.0	24.4	41.8

*Only one sample of cultivar tested

Protein content of lentils ranged from 22.6 to 27.7% with a mean value of 24.9% (Table 19). The mean protein content of lentils grown in 2022 was higher than the 5-and 10-year mean protein contents of 24.3% and 23.8%, respectively. The protein contents of the two market classes were different (Table 20). Green lentils had the highest mean protein content (25.7%) among the lentil market classes while the Spanish brown lentils had a mean protein value of 24.4 (Table 20). The mean protein content of the green lentils from 2022 was higher than the 5- and 10-year mean protein contents. The protein content of the Spanish brown lentils also was higher than the 5-year mean protein content. The Merrit (green) cultivars had the highest protein percentage among tested cultivars (Table 21). This same cultivar also had the highest protein content in 2021.

Total starch

Total starch content of lentils ranged from 37.8 to 43.4%, with a mean of 43.0% (Table 19). The mean total starch percentage of lentils grown in 2022 was lower than starch percentage in lentils from the previous five and ten years. The mean 5- and 10-

year starch contents were 43.7 and 44.9%, respectively. The mean starch content in peas grown in 2022 was approximately 2 to 4 percentage points lower than peas from 2019-2021. The Spanish brown market class had higher (41.8%) starch content than the green market class (39.0%) (Table 20). Regardless of the market class, the lentils produced in 2022 had mean starch contents that were lower than lentils from other crop years. The starch content of 39.0% for the green lentils from 2022 was substantially lower than the starch 5- and 10-year mean starch contents of 43.4 and 45.0%, respectively. In the Spanish brown market class, the mean starch content in 2022 was 41.8% while the 5-year mean starch content was 44.1% (Table 20). The higher protein observed in 2022 may contribute to the lower starch percentage. The highest mean starch content was observed in Pardina (Spanish brown) cultivar at 41.8% (Table 21). The Merrit cultivar had the lowest starch content (38.7%) among cultivars tested. This cultivar also had the highest protein content and thus supports the assumption that the higher protein percentage contributed to the lower starch percentage. A plausible explanation is that the drought stress caused a reduction in carbohydrates and thus caused a greater portion of the seed to be protein.

Physical parameters of lentils (Tables 22-24)

Test weight, 1000 seed weight, water hydration capacity, percentage unhydrated seeds, swelling capacity, cooking firmness and color represent the physical parameters used to define physical quality. **Test weight** ranged from 59.4-66.5 lbs./Bu with a mean of 64.1 lbs./Bu. This mean value was comparable to the mean test weight of lentils from 2020 and 2021. Furthermore, the mean value was higher than the 5- and 10-year mean test weight of 63.2 and 62.5 lbs./Bu, respectively (Table 22). Similar to 2020 and 2021, the mean test weight of lentils in the Spanish brown market class was approximately 5 percentage points higher than test weights of lentils from the green market class (Table 23). The mean test weight for lentils in the Spanish brown market class in 2022 was higher than the 5-year mean test weight. In contrast. The lentils in the green market class from 2022 had a lower mean test weight compared to the 5- and 10-year mean test weight. The highest test weight of 66.5 lbs./Bu was observed in a sample of the Pardina cultivar while one sample of Merrit had test weight of 59.4 lbs./Bu, which was the lowest test weight value recorded. Overall, the Pardina and Merrit cultivars had the highest and lowest mean test weights among cultivars tested (Table 24). The Merrit cultivar also had the lowest mean test weight (61.7 and 59.7 lbs./Bu) in 2020 and 2021, respectively.

Table 22. Physical parameters of lentils grown in the USA, 2018-2022.

Physical Parameters	2022		2021	2020	2019	2018	5-year	10-year
	Range	Mean (SD)	Mean	Mean	Mean	Mean	Mean (SD)	Mean (SD)
Test Weight (lb/Bu)	59.4-66.5	64.1 (2.6)	64.3 (2.9)	64.3 (2.0)	62.4 (2.5)	62.9 (2.2)	63.2 (1.0)	62.5 (1.2)
1000 Seed Wt (g)	20-58	40 (11)	45 (13)	48.0 (10.0)	42.8 (10.8)	42 (9)	44 (2)	44 (2)
Water Hydration Capacity (%)	80-109	94 (8)	87 (8)	91 (21)	91 (8)	99 (2)	94 (6)	96 (9)
Unhydrated Seeds (%)	1-24	9 (7)	4 (4)	5 (6)	4 (4)	2 (3)	3 (2)	4 (2)
Swelling Capacity (%)	75-154	101 (18)	98 (15)	117 (21)	143 (15)	140 (15)	128 (20)	nd
Cooked Firmness (N/g)	12.3-28.7	17.9 (4.1)	19.8 (4.2)	19.9 (4.3)	15.8 (4.8)	15 (3)	17.1 (2.6)	nd

nd = not determined due to test not being performed for 10 years.

The range and mean **1000 seed weight** of lentils grown in 2022 were 20 to 58 g and 40.0 g, respectively (Table 22). The mean 1000 seed weight was significantly lower than the 5- and 10-year mean values of 44 g. This data supports smaller seed size of the lentils in 2022. However, lentils from the green market class had a mean 1000 seed weight of 55 g, which is higher than the mean 1000 seed weights for green lentils grown in 2018-2020. Furthermore, the mean 1000 seed weight is higher than the 5- and 10-year mean values (Table 23). The lentils from the green market class supports larger seed size compared to previous evaluations while lentils from the Spanish brown market class represent a smaller seed size in 2022. This is supported by the lower (32 g) 1000 seed weight in 2022 compared to the 5-year mean value of 38.4 g. As expected, the Pardina cultivar had the lowest (32 g) 1000 seed weight while Avondale had the highest (56 g) 1000 seed weight among lentils from 2022 (Table 24).

Water hydration capacity of lentils ranged from 80 to 109%, with a mean of 94% (Table 22). The mean water hydration capacity value of lentils from 2022 was lower than lentils that made up the 10-year mean water hydration capacity. However, the mean water hydration capacity (94%) was the same as the lentils that made up the 5-year mean water hydration capacity. The water hydration capacity (99%) was highest for the green lentils while the Spanish brown market classes had slightly lower (92%) water hydration capacities (Table 23). The green lentils from 2022 had water hydration capacities that were significantly lower than the 5-year mean value but comparable to the lentils from 2018 and the 10-year mean water hydration capacity. Spanish brown lentils had comparable water hydration capacity to the 5-year mean value (Table 23) and lentils from 2018 and 2019. The mean water hydration capacity ranged from 92% to 109% in Pardina and Avondale cultivars, respectively (Table 24).

Table 23. Physical parameters of different market classes of lentils grown in the USA, 2018-2022 plus 5- and 10-year mean values.

Market class	Physical Parameter	2022	2021	2020	2019	2018	5-Year Mean	10-Year Mean
Green	Test Weight (lb/Bu)	61.0 (1.8)	62.3 (2.5)	63.6 (1.8)	61.8 (2.4)	62.2 (1.8)	62.1 (0.9)	62.2 (0.8)
	1000 Seed Wt (g)	55 (3)	51 (13)	51 (10)	46 (12)	47 (8)	49 (2)	46 (5.9)
	Water Hydration Capacity (%)	99 (7)	85 (9)	88 (11)	93 (6)	100 (9)	105 (24)	100 (19.6)
	Unhydrated Seeds (%)	3 (3)	3 (3)	6 (7)	2 (2)	1 (1)	3 (2)	3 (3.1)
	Swelling Capacity (%)	116 (19)	97 (13)	117 (18)	145 (11)	140 (15)	120 (22)	nd
	Cooked Firmness (N/g)	16.6 (1.4)	19.7 (4.7)	19.2 (4.2)	15.5 (5.3)	14.5 (3.8)	16.8 (2.5)	nd
Red	Test Weight (lb/Bu)	*	64.7 (0)	63.9 (2.5)	64.2 (0.4)	61.6 (2.1)	63.5 (1.2)	62.6 (1.7)
	1000 Seed Wt (g)	*	63 (0)	43 (9)	36.8 (6)	41 (5)	44 (11)	43 (8.5)
	Water Hydration Capacity (%)	*	93 (0)	126 (41)	84 (8)	106 (12)	112 (20)	103 (17.1)
	Unhydrated Seeds (%)	*	3 (0)	5 (6)	8 (1)	1 (1)	4 (3)	4 (2.3)
	Swelling Capacity (%)	*	128 (0)	138 (35)	140 (5)	143 (15)	136 (6)	nd
	Cooked Firmness (N/g)	*	19.6 (0)	21.7 (5.3)	14.8 (5.7)	15.2 (3.5)	17.2 (3.2)	nd
Spanish Brown	Test Weight (lb/Bu)	65.7 (1.0)	66.7 (0.7)	66.1 (1.0)	62.4 (2.0)	65.4 (0.6)	64.9 (1.7)	nd
	1000 Seed Wt (g)	32 (2)	35 (3)	42 (4)	43 (7)	32 (2)	38.4 (5)	nd
	Water Hydration Capacity (%)	92 (8)	88 (6)	81 (13)	91 (8)	93 (10)	91 (8)	nd
	Unhydrated Seeds (%)	12 (6)	6 (3)	5 (4)	3.9 (6)	6 (3)	4.8 (1)	nd
	Swelling Capacity (%)	93 (12)	97 (16)	109 (15)	143 (21)	137 (16)	126 (22)	nd
	Cooked Firmness (N/g)	18.5 (4.9)	19.8 (4.0)	21.7 (3.9)	15.8 (2.8)	15.5 (1.8)	17.3 (3.3)	nd

* no red lentils evaluated in 2022; nd = not determined due to test not being performed for 10 years.

Unhydrated seed percentage ranged from 1 to 24% with a mean of 9 %, which is greater than the 5- and 10-year mean of 3 and 4%, respectively (Table 22). Many of the samples had unhydrated seed rates around 12-14%, which likely contributed to 9% unhydrated seed rate in 2022. The mean unhydrated seeds in both market classes varied from 3 to 12% (Table 23). The green lentils from 2022 had mean unhydrated seed percentage that was the same as the 5- and 10-year mean unhydrated seed percentage. For the Spanish brown lentils, the unhydrated seed count in was significantly higher (12%) than the 5-year mean unhydrated seed percentage (4.8%). This indicates that the drought conditions only impacted the Spanish brown market classes. The Avondale cultivar had the lowest unhydrated seed percentage at 2% while the Pardina cultivar had the highest at 12% (Table 24). The unhydrated seed percentage follows the trends of previous years where the Spanish brown seeds tended to hydrate less than the green lentils.

The **swelling capacity** of all lentils ranged from 75 to 154%, with a mean value of 101% (Table 22). The mean swelling capacity from 2022 samples were comparable to the lentils from 2021 but significantly lower than that of lentils from the previous years, including the 5-year mean swelling capacity. This observation supports that the dry growing conditions likely affected the lentil compositionally and structurally and inhibited water uptake, which is important for a full rehydration of the seed and the accompanying swelling of the seed. The mean swelling capacity of lentils from the green market class was 116 % (Table 23). The swelling capacity of the green lentils was comparable to lentils from 2020 but was less than the 5-year mean swelling capacities of 120%. The mean swelling capacity (93%) of the Spanish brown lentils in 2022 was similar to the mean swelling capacity (97%) for the Spanish brown lentils from 2021. However, the mean swelling capacity of the Spanish brown lentils in 2022 was significantly lower than the 5-year mean swelling capacity (Table 23). The greatest swelling capacity (154%) was observed in the Avondale cultivar while the Pardina cultivar lentil had the lowest (92%) mean swelling capacity (Table 24). The low swelling capacity among the Pardina lentils was 75%. The reason for this might be due to the low water uptake as supported by the high number of unhydrated seeds and low water hydration capacity.

Table 24. Mean physical parameters of USA lentil cultivars grown in 2022.

Market Class	Cultivar	Test Weight (lb/bu)	1000 Seed Wt (g)	Water Hydration Capacity (%)	Unhydrated Seeds (%)	Swelling Capacity (%)	Cooked Firmness (N/g)
Green	Avondale*	64.4	56	109	2	154	17.9
	Merrit	60.3	54	97	4	109	16.3
Spanish Brown	Pardina	65.7	32	92	12	93	18.5

*Only one sample of cultivar tested

The **cooked firmness** of all lentils ranged from 12.3 to 28.7 N/g with a mean value of 17.9 N/g (Table 22). The lentils from 2022 had similar cooked firmness values to lentils included in the 5-year mean cooked firmness (17.1 N/g). The cooked firmness of lentils from 2022 fell in between the values from 2020 and 2021(~20 N/g) and 2018 and 2019 (~15.5 N/g). The cooked firmness of lentils was not substantially different between the market classes; however, the Spanish brown market class had cooked firmness values that were 2 percentage points higher than the values from the green lentils (Table 23). The lentils from the green market class had a mean cooked firmness value (16.6 N/g) that was comparable to the 5-year mean cooked firmness (16.8 N/g). In contrast, the mean cooked firmness of Spanish brown lentils was 1 N/g higher for the lentils from 2022 compared to the 5-year mean value. Among the cultivars, Pardina had the highest cooked firmness value followed by Avondale and Merrit (Table 24).

Color quality was measured using L*, a*, and b* values and from these values a color difference can be determined on lentils before and after soaking (Table 25). Color quality for all lentils in 2022 indicated that the lentils had higher L* values than in lentils from previous years except 2020. This data indicates that the lentils from the 2022 crop year were lighter in color than those from previous years. The L* value of the green lentils was higher than the 5- and 10-year mean L* value while the Spanish brown lentils had a mean L* value that

was greater than the 5-year mean L* value (Table 25). The lower a* value (i.e., green-red scale) in the green lentil indicates a less red color while a negative a* value for the green lentils indicates a greener color. In 2022, the a* value of 2.72 indicates that the lentils had similar greenness to the lentils from 2021 but were less green compared to lentils from 2019 and 2020 harvest years. However, green lentils had a* values that were lower than the 5- and 10-year mean a* values, indicating a greener lentil for the 2022 samples. The mean a* value for the Spanish brown lentils was lower than the 5-year mean a* value indicating less redness. The green lentils had a lower mean b* value than the 5- and 10-year mean values suggesting the 2022 samples are less yellow in nature. The Spanish brown mean b* value for 2022 was greater than the b* value of samples from 2020 and 2021but comparable to the samples from 2019. However, Spanish brown mean b* value for 2022 was lower than the 5-year mean b* values. This indicates that the lentils were a darker brown compared to the 5-year mean due to the lower yellowness of the lentil in 2022. The color of the lentils changed after the soaking process. Green and Spanish brown market classes became lighter as evidenced by the slightly higher L* values (Table 25) compared to pre-soaked lentils. In the green and Spanish brown market classes, the decreased a* value indicated an increase in greenness of the lentils after soaking. Lentils from all market classes became more yellow (i.e., increased b* value) after soaking. The color difference in lentil samples was comparable between market classes (Table 25). Overall, the colors were less impacted (lower value) by soaking in comparison to lentils used to determine the 5-year mean color difference value.

Table 25. Color quality of lentils grown in the USA before and after soaking, 2019-2022 plus 5- and 10-year mean values.

Color Scale	Mean (SD) of green lentils											
	Before Soaking						After Soaking					
	2022	2021	2020	2019	5-Year	10-year	2022	2021	2020	2019	5-Year	10-Year
L (lightness)	58.82 (0.77)	57.10 (0.96)	59.75 (1.45)	48.07 (1.91)	55.00 (4.40)	57.05 (4.16)	59.02 (0.45)	56.69 (2.59)	60.15 (3.93)	52.93 (1.52)	46.25 (24.20)	53.77 (18.13)
a (red-green)	2.72 (0.82)	3.20 (1.85)	0.83 (1.05)	0.53 (1.43)	4.65 (4.73)	3.48 (3.53)	1.20 (1.33)	2.00 (1.35)	-0.12 (4.00)	-0.98 (2.86)	12.83 (24.64)	6.88 (17.63)
b (yellow-blue)	11.73 (1.13)	12.22 (2.10)	15.39 (0.95)	13.54 (3.45)	14.86 (8.08)	17.04 (6.42)	19.93 (3.04)	14.23 (3.89)	20.48 (5.52)	20.48 (2.35)	23.58 (7.56)	26.23 (6.60)
Color Difference	8.38 (1.99)	5.57 (1.48)	8.23 (4.79)	9.31 (3.40)	8.81 (2.04)	nd						
Color Scale*	Mean (SD) of red lentils											
	Before Soaking						After Soaking					
	2022	2021	2020	2019	5-Year	10-Year	2022	2021	2020	2019	5-Year	10-Year
L (lightness)	**	53.60 (0)	55.13 (2.32)	44.84 (2.08)	50.18 (4.51)	51.87 (4.56)	**	54.52 (0)	55.05 (3.93)	48.83 (2.48)	41.84 (21.62)	47.21 (15.59)
a (red-green)	**	3.47 (0)	2.88 (1.91)	3.38 (0.60)	5.27 (2.14)	5.15 (1.85)	**	5.48 (0)	5.36 (3.42)	9.35 (1.84)	19.10 (20.06)	14.35 (14.38)
b (yellow-blue)	**	5.29 (0)	11.07 (4.09)	9.36 (1.49)	11.45 (4.52)	12.17 (4.34)	**	10.21 (0)	14.67 (2.55)	19.05 (2.52)	20.11 (8.11)	21.69 (6.27)
Color Difference	**	5.40 (0)	7.40 (3.28)	12.12 (1.96)	10.77 (4.28)	nd	**					
Color Scale	Mean (SD) of brown lentils											
	Before Soaking						After Soaking					
	2022	2021	2020	2019	5- Year	10-Year	2022	2021	2020	2019	5-Year	10-Year
L (lightness)	54.01 (0.36)	51.11 (0.47)	51.97 (0.33)	39.52 (2.39)	45.98 (5.40)	nd	54.71 (0.73)	52.42 (1.22)	53.96 (0.44)	39.03 (3.65)	38.88 (20.69)	nd
a (red-green)	2.65 (0.23)	3.17 (0.26)	0.66 (1.48)	1.72 (0.58)	4.09 (2.76)	nd	2.20 (0.43)	2.99 (0.56)	-0.90 (0.70)	2.93 (1.25)	13.84 (21.85)	nd
b (yellow-blue)	6.78 (0.21)	6.93 (0.47)	8.60 (1.58)	6.48 (1.63)	8.72 (4.21)	nd	15.42 (1.12)	11.96 (4.85)	10.13 (1.54)	14.69 (1.34)	18.93 (9.28)	nd
Color Difference	8.69 (1.11)	5.58 (4.33)	3.53 (1.79)	8.72 (1.03)	10.60 (6.72)	nd						

*color scale L (lightness) axis – 0 is black and 100 is white; a (red-green) axis – positive values are red, negative values are green, and zero is neutral; and b (yellow-blue) axis – positive values are yellow, negative values are blue, and zero is neutral. Color difference = change in value before soaking and after soaking. **no red lentils evaluated in 2022; nd = not determined due to test not being performed for 10 years.

Among the cultivars, Pardina had the lowest L* value followed by Merrit (Table 26). The highest L* was observed in the Avondale green lentil. This follows expectations that the brown lentils would be darker than the green lentils. The L* values of lentil increased for the brown lentils after soaking. In contrast, mixed results were observed in the green cultivars were L* increased after soaking in some samples but not others (Table 26). The green and Spanish brown lentil cultivars became greener (i.e., reduction of the a* value) after soaking. Furthermore, the increased b* values indicated that the lentils in both market classes became more yellow. The green lentil cultivar Avondale had the highest b* value (i.e., yellowness) of the soaked lentils. This is a green coated lentil, but has a yellow cotyledon; thus, the soaking may have reduced the impact of the hull on color and resulted in increased yellowness. The greatest color difference was observed the Avondale cultivar (Table 26). The increase in greenness and yellowness during soaking likely contributed to the greatest color difference in this cultivar. The color of Merrit was the most stable as this cultivar had the lowest color difference value (i.e., 7.61).

Table 26. Color quality of USA lentil cultivars before and after soaking, 2022.

		Mean Color Values*						
		Before Soaking			After Soaking			Color
Market Class	Cultivar	L	a	b	L	a	b	Difference
Green	Avondale**	59.93	1.07	13.93	59.43	-1.41	25.92	12.26
	Merrit	58.60	3.05	11.29	58.93	1.72	18.73	7.61
Spanish Brown	Pardina	54.01	2.65	6.78	54.71	2.20	15.42	8.69

*color scale L (lightness) axis – 0 is black and 100 is white; a (red-green) axis – positive values are red, negative values are green, and zero is neutral; and b (yellow-blue) axis – positive values are yellow, negative values are blue, and zero is neutral; **Only one sample of cultivar tested.

Pasting properties (Tables 27-29)

Peak, hot paste and cold paste viscosities of lentils grown in 2022 were significantly lower than their respective values from lentils of other harvest years except for lentils from 2021. For example, a significantly lower cold paste viscosity (221 RVU) was observed for lentils from 2022 (Table 27) compared to other harvest years and the 5-year mean cold paste viscosity. However, pasting viscosities of lentils from 2022 were comparable to the 10-year mean value. Pasting temperature ranged from 78.4 to 83.2 °C, with a mean value of 80.2 °C, which is higher than the 5-year mean pasting temperature. The peak, hot paste and cold paste viscosities were different among the market classes (Table 28). The peak, hot paste and cold paste viscosities obtained for lentils in the green market class were lower than the lentils from the Spanish brown market class. This general observation was also observed in samples from previous years. This suggests a thinner final viscosity for green lentil flours compared to Spanish brown lentils. Pasting characteristics for all market class in 2022 were lower than the 5-year mean viscosity value and for the green market class, their values were lower than the 10-year mean viscosity values. This indicates that the lentils from 2022 produce thinner pastes and gels. As with peas, the growing environment and lower starch contents may have contributed to the pasting characteristics. New in 2022 was the RVA gel firmness. The gel firmness ranged from 235-347 g with a mean of 285 g.

Table 27. Starch characteristics of lentils grown in the USA, 2018-2022 plus 5- and 10-year mean values.

Starch	2022		2021	2020	2019	2018	5-year	10-year
Characteristic	Range	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Peak Viscosity (RVU)	88-166	124 (19)	117 (23)	142 (21)	146 (14)	142 (18)	138 (12)	133 (13)
Hot Paste Viscosity (RVU)	84-157	120 (18)	110 (23)	133 (17)	137 (11)	134 (14)	130 (11)	124 (11)
Breakdown (RVU)	3-9	4 (3)	7 (7)	9 (6)	9 (6)	8 (6)	8 (1)	8 (3)
Cold Paste Viscosity (RVU)	169-287	221 (32)	210 (50)	237 (35)	253 (28)	245 (29)	240 (18)	225 (22)
Setback (RVU)	78-133	101 (16)	100 (28)	104 (21)	117 (19)	111 (16)	110 (8)	101 (12)
Peak Time (Minute)	5.07-7.00	6.46 (0.56)	6.10 (0.76)	5.68 (0.62)	5.49 (0.52)	5.85 (0.76)	5.75 (0.23)	6.47 (1.58)
Pasting Temperature (°C)	78.4-83.2	80.2 (1.4)	80.0 (1.8)	78.9 (1.5)	77.1 (1.2)	77.8 (1.8)	78.3 (1.1)	nd
RVA Gel Firmness (g)	235-347	285 (35)	**	**	**	**	nd	nd

**not previously reported; nd = not determined due to test not being performed for 5 or 10 years.

Table 28. Starch characteristic of different market classes of lentils grown in the USA, 2018-2022 and 5- and 10-year mean values.

Market class	Physical Parameter	Mean (SD) 2022	2021	2020	2019	2018	5-Year Mean (SD)	10-Year Mean (SD)
Green	Peak Viscosity (RVU)	110 (15)	111 (22)	146 (21)	142 (13)	145 (18)	138 (15)	141 (22)
	Hot Paste Viscosity (RVU)	105 (14)	103 (21)	135 (17)	133 (8)	134 (14)	129 (14)	128 (13)
	Breakdown (RVU)	5 (2)	8 (9)	10 (6)	8 (5)	10 (6)	9 (1)	13 (11)
	Cold Paste Viscosity (RVU	194 (15)	193 (41)	241 (35)	242 (26)	248 (30)	236 (25)	237 (38)
	Setback (RVU)	89 (7)	90 (21)	106 (22)	109 (19)	113 (17)	107 (11)	95 (21)
	Peak Time (Minute)	6.55 (0.67)	6.11 (0.83)	5.54 (0.55)	5.53 (0.54)	5.59 (0.16)	5.67 (0.25)	6.22 (1.56)
	Pasting Temperature (°C)	81.2 (1.9)	80.6 (2.1)	78.7 (1.6)	76.8 (1.5)	77.3 (2.0)	78.2 (1.5)	nd
	RVA Gel Firmness (g)	268 (34)	**	**	**	**	nd	nd
Red	Peak Viscosity (RVU)	*	97 (0)	130 (21)	148 (9)	122 (8)	126 (19)	126 (24)
	Hot Paste Viscosity (RVU)	*	84 (0)	123 (17)	134 (6)	121 (8)	118 (20)	117 (18)
	Breakdown (RVU)	*	13 (0)	7 (6)	14 (7)	1 (0)	8 (5)	10 (10)
	Cold Paste Viscosity (RVU	*	132 (0)	218 (39)	249 (13)	214 (17)	211 (46)	215 (49)
	Setback (RVU)	*	48 (0)	95 (23)	115 (12)	93 (9)	93 (27)	98 (32)
	Peak Time (Minute)	*	5.27 (0)	5.77 (0.53)	5.37 (0.36)	6.57 (0.65)	5.77 (0.51)	6.53 (1.76)
	Pasting Temperature (°C)	*	79.2 (0)	79.0 (1.8)	78.0 (0.7)	79.0 (1.3)	78.7 (0.6)	nd
	RVA Gel Firmness (g)	*	**	**	**	**	nd	nd
Spanish Brow	Peak Viscosity (RVU)	130 (17)	126 (24)	139 (21)	153 (13)	143 (15)	142 (11)	nd
	Hot Paste Viscosity (RVU)	127 (15)	121 (23)	132 (18)	143 (10)	139 (12)	136 (9)	nd
	Breakdown (RVU)	4 (3)	5 (4)	6 (5)	9 (6)	5 (3)	6 (2)	nd
	Cold Paste Viscosity (RVU	234 (30)	237 (49)	235 (33)	249 (26)	253 (22)	248 (12)	nd
	Setback (RVU)	108 (16)	116 (27)	102 (16)	129 (18)	114 (11)	116 (10)	nd
	Peak Time (Minute)	6.42 (0.50)	6.16 (0.68)	6.03 (0.70)	5.45 (0.58)	6.19 (0.84)	5.88 (0.34)	nd
	Pasting Temperature (°C)	79.7 (0.5)	79.3 (1.0)	79.5 (0.8)	77.4 (0.6)	78.2 (1.3)	78.5 (0.9)	nd
	RVA Gel Firmness (g)	293 (33)	**	**	**	**	nd	nd

* no red lentils evaluated in 2022; **not previously measured; nd = not determined due to test not being performed for 5 or 10 years.

Variability in pasting characteristics were observed among cultivars (Table 29). In the green market class, the variability among cultivars was noticeable. Merrit had the lowest (105 RVU) peak viscosity in 2022, which also was the case in 2020 (114 RVU) and 2021 (90 RVU). Merrit also had the lowest hot paste (101 RVU) and cold paste (189 RVU) viscosities among the lentil cultivars evaluated in 2022. Avondale and Pardina had comparable peak, hot paste, and cold paste viscosities. The pasting viscosities of the Pardina lentils from 2022 mirror results from Pardina lentils from 2021. Overall, lentils had pasting temperatures that were slightly lower in the 2022 harvest year compared to the same cultivar grown in 2021. The Spanish brown market class had greater RVA gel firmness values overall than the green lentils. However, the Avondale cultivar produced the firmest (338 g) gel among samples (Table 29).

Table 29. Mean starch characteristics of lentil cultivars grown in the USA in 2022.

Market Class	Cultivar	Peak Viscosity (RVU)	Hot Paste Viscosity (RVU)	Breakdown (RVU)	Cold Paste Viscosity (RVU)	Setback (RVU)	Peak Time (Min)	Pasting Temperature (°C)	RVA Gel Firmnes (g)
Green	Avondale*	134	126	9	221	95	5.07	78.4	338
	Merrit	105	101	4	189	88	6.85	81.8	254
Spanish Brown	Pardina	130	127	4	234	108	6.42	79.7	293

*Only one sample of cultivar tested.

Functional properties (Tables 30-32)

Functionality property evaluation is new in 2022. These tests include emulsion activity and stability, foaming capacity and stability, water holding capacity and oil holding capacity. The emulsion activity and stability for all lentil samples ranged from 56-62% and 56-61% (Table 30). However, the lentils from the various market classes had comparable emulsion activity and stability (Table 31). Furthermore, no one cultivar had emulsion activity and stability values that were substantially different from others. However, Avondale did have an emulsion activity that was 3 to 4 percentage points higher than the emulsion activity of Merrit and Pardina cultivars (Table 32). In contrast to emulsion activity, foaming capacity varied to a greater extent (143-327%). Differences in foaming capacity among different classes of lentils was observed (Table 31), with the green lentils having mean foaming capacities that were approximately 40 percentage points higher than the mean foaming capacity of the Spanish brown lentils. In contrast, the Spanish brown lentils had foam stability that were approximately 15 percentage higher than the foaming stability of the green lentils. The Avondale cultivar had significantly higher foaming capacity (327%) compared to other cultivars while stability was similar to Pardina (Table 32). The Avondale cultivar had higher water holding capacity compared to the other cultivars, which may be responsible for the higher emulsion capacity. For oil holding capacity, Merrit had substantially higher (i.e., 0.68 vs. 0.22 g/g) values compared to the other samples.

Table 30. Functional properties of lentils grown in the USA, 2022.

Functional Properties	Year 2022	
	Range	Mean (SD)
Emulsion Activity (%)	56-62	59 (1)
Emulsion Stability (%)	56-61	59 (2)
Foaming Capacity (%)	143-327	205 (45)
Foam Stability (%)	40-92	67 (14)
Water Holding Capacity (g/g)	1.10-1.68	1.30 (0.16)
Oil Holding Capacity (g/g)	0.17-0.99	0.40 (0.28)

Table 31. Functional properties of different market classes of lentils grown in the USA, 2022.

Functional Properties	Mean (SD)	
	Green	Spanish Brown
Emulsion Activity (%)	59 (2)	58 (1)
Emulsion Stability (%)	57 (1)	59 (2)
Foaming Capacity (%)	237 (49)	189 (36)
Foam Stability (%)	58 (14)	71 (12)
Water Holding Capacity (g/g)	1.34 (0.25)	1.28 (0.11)
Oil Holding Capacity (g/g)	0.60 (0.29)	0.29 (0.21)

Table 32. Mean functional properties of lentil cultivars grown in the USA, 2022.

Market Class	Cultivar	Emulsion Activity (%)	Emulsion Stability (%)	Foaming Capacity (%)	Foam Stability (%)	Water Holding Capacity (g/g)	Oil Holding Capacity (g/g)
Green	Avondale*	62	57	327	74	1.68	0.22
	Merrit	59	57	219	55	1.28	0.68
Spanish Brown	Pardina	58	59	189	71	1.28	0.29

*Only one sample of cultivar tested

Chickpea Quality Results

Sample distribution

A total of 25 chickpea samples were collected from Idaho, Montana, North Dakota, and Washington between August 2022 to January 2023. Samples were delivered to SDSU between January 2023 and April 2023. Growing location, number of samples, market class, and genotype details of these dry chickpea samples are provided in Table 33. Royal (5), and Sierra (17) accounted for most of the chickpea evaluated.

Table 33. Description of chickpea samples used in the 2022 pulse quality survey.

State	No. of Samples	Market Class	Cultivars	
Idaho	7	Kabuli	Royal	Sierra
Montana	2	Kabuli	CDC Orion	
North Dakota	1	Kabuli	NDC160236	
Washington	15	Kabuli	Royal	Sierra

Proximate composition of chickpea (Tables 34-35)

The **moisture content** of chickpeas ranged from 5.6 to 10.1% in 2022 (Table 34). The mean moisture content of the samples was 8.5%, which is lower than the 5-year mean of 9.1%. However, chickpeas grown in 2022 had approximately the same mean moisture value as the samples from 2021 and the 10- year mean moisture content (8.5%). This supports that the long-term mean moisture content of the chickpea from the region is consistent. No sample exceed the 13-14% moisture threshold for proper storage. Royal had the highest mean moisture content at 8.9% while the CDC Orion of the commercial cultivars had the lowest moisture (8.3%) among all chickpea (Table 35).

Ash content of chickpeas ranged from 2.7 to 3.2% with a mean of 2.9% (Table 34). The mean ash content of chickpeas grown in 2022 was comparable to ash contents of chickpea that were used in determining the 5- and 10-year mean values

Table 34. Proximate composition of Kabuli chickpeas grown in the USA, 2018-2022 plus 5- and 10-year mean values.

Proximate Composition*	Year							
	2022		2021	2020	2019	2018	5-year	10-year
	Range	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Moisture (%)	5.6-10.1	8.5 (0.9)	8.5 (0.9)	7.9 (1.1)	11.6 (2.6)	8.8 (0.9)	9.1 (1.4)	8.5 (2.3)
Ash (%)	2.7-3.2	2.9 (0.1)	3.0 (0.2)	3.0 (0.6)	2.6 (0.2)	2.8 (0.2)	2.8 (0.2)	2.8 (0.2)
Fat (%)	5.2-7.0	5.6 (0.4)	5.6 (0.3)	5.4 (0.6)	6.1 (0.5)	7.2 (1.1)	6.1 (0.7)	nd
Protein (%)	15.4-24.4	20.8 (2.3)	19.8 (1.5)	21.1 (2.0)	19.4 (1.9)	20.8 (2.3)	20.1 (0.8)	20.0 (1.0)
Starch (%)	37.4-45.6	41.3 (2.4)	40.7 (1.3)	40.8 (3.6)	40.1 (1.8)	41.1 (2.5)	40.5 (0.6)	42.8 (4.7)

*composition is on an "as is" basis; nd = not determined due to test not being performed for 10 years.

(Table 34). Of the commercial cultivars grown, Sierra had the lowest ash contents at 2.9%, while CDC Orion and Royal had ash contents of 3.0%, thus indicating minimal variability of the ash / mineral composition (Table 35). The mean **fat content** was 5.6% with a range from 5.2 to 7.0% (Table 34). Literature reports indicate that chickpea has a fat content between 2 and 7%; therefore, the fat content of chickpeas grown in 2022 fall within the range reported by others but less than the fat content recorded in previous years except for chickpeas from 2020 and 2021. Fat content was slightly lower than the 5-year mean fat content of 6.1% (Table 34). The CDC Orion cultivar had the highest (5.7%) fat content among Kabuli chickpeas (Table 35). However, the fat content of CDC Orion was not substantially different from fat contents of Royal and Sierra.

Protein content of chickpeas ranged from 15.4 to 24.4%, with a mean of 20.8% (Table 34). The mean protein content of chickpea grown in 2022 was slightly higher than the 5- and 10-year mean protein contents of 20.1 and 20.0%, respectively. Royal had the lowest (20.2%) mean protein content while Sierra had the highest mean protein content at 21.3% (Table 35). In 2021, Royal and Sierra chickpeas had mean protein contents of 20.1 and 19.7%, respectively. **Total starch content** of chickpea ranged from 38.2 to 44.6%, with a mean of 40.7% (Table 33). The mean total starch content of chickpeas grown in 2022 was similar to the mean starch content observed in chickpea from the 2018 harvest year and was slightly higher than the 5-year mean of 40.5%. However, the starch content was lower than the 10- year mean value (42.8%). The CDC Orion cultivar had the lowest (40.7%) mean starch content while the highest (41.3%) was observed in the Royal cultivar.

Table 35. Mean proximate composition of chickpea cultivars grown in the USA, 2022.

Market Class	Cultivar	Concentration (%)				
		Moisture	Ash	Fat	Protein	Starch
Kabuli	CDC Orion*	8.3	3.0	5.7	20.9	40.7
	NDC160236*	5.6	3.2	6.3	19.5	41.4
	Royal	8.9	3.0	5.5	20.2	41.3
	Sierra	8.5	2.9	5.6	21.3	41.1

* Value from only one sample.

Physical parameters of chickpeas (Tables 36-39)

Test weight, 1000 seed weight, water hydration capacity, percentage unhydrated seeds, swelling capacity, cooked firmness and color represent the physical parameters used to define physical quality. The data presented also include size distribution. Test weight ranged from 55.5 to 64.0 lbs./Bu with a mean of 61.2 lbs./Bu. This mean value is approximately the same as both the 5- and 10-year mean test weight (Table 36). The data supports the uniformity in test weight over the long-term. The test weights of individual cultivars ranged from 56.3 lbs./Bu in CDC Orion to 62.1 lbs./Bu in the Royal cultivars (Table 37). The range and mean 1000 seed weight of chickpeas grown in 2022 were 344-591 g and 477 g, respectively (Table 36). The mean 1000 seed weight was significantly greater than the 5-year and 10-year mean of 431 and 419 g, respectively. The Royal cultivar had a highest 1000 seed weight at 532 g while the CDC Orion cultivar had the lowest value at 393 g (Table 37).

Table 36. Physical parameters of Kabuli chickpeas grown in the USA, 2018-2022 plus 5- and 10-year mean values.

Physical Parameter	Year						5-year	10-year
	2022		2021	2020	2019	2018		
	Range	Mean (SD)	Mean	Mean	Mean	Mean	Mean (SD)	Mean (SD)
Test Weight (lb/Bu)	55.5-64.0	61.2 (1.9)	61.2(1.8)	61.6 (1.5)	61.0 (1.0)	62.0 (1.4)	61.4 (0.4)	61.2 (0.6)
1000 Seed Wt	344-591	477 (50)	464 (67)	417 (71)	444 (74)	410 (71)	431 (22)	419 (25)
Water Hydration Capacity (%)	90-117	105 (7)	105 (9)	108 (8)	102 (8)	102 (10)	104 (2)	105(4)
Unhydrated Seeds (%)	0-0	0 (0)	0 (0)	0 (0)	0 (0)	0 (2)	0 (0)	1(1)
Swelling Capacity (%)	100-158	125 (12)	144 (20)	145 (17)	138 (15)	130 (14)	137 (8)	nd
Cooked Firmness (N/g)	13.7-26.7	18.6 (2.9)	19.7 (2.3)	19.6 (2.9)	20.7 (3.8)	27.9 (6.1)	22.8 (3.9)	nd
% of Sample Retained on 22/64 Sieve	25.8-98.0	79.5 (15.3)	69.0 (21.5)	55.6 (26.5)	64.2 (28.3)	*	nd	nd
% of Sample Retained on 20/64 Sieve	2.0-55.0	16.7 (11.9)	22.8 (12.6)	34.3 (18.6)	29.1 (20.8)	*	nd	nd
% of Sample Retained on 18/64 Sieve	0.0-14.9	3.6 (3.2)	7.1 (9.9)	9.7 (12.4)	6.1 (10.0)	*	nd	nd
% of Sample Passed Through an 18/64 Sieve	0.0-4.3	0.3 (0.9)	1.1 (2.5)	0.4 (0.9)	0.6 (1.0)	*	nd	nd

*value not measured; nd = not determined due to test not being performed for 5 or 10 years.

Table 37. Mean physical properties of chickpea cultivars grown in the USA, 2022.

Market Class	Cultivar	Test Weight (lb/Bu)	1000 Seed Wt (g)	Water Hydration Capacity (%)	Unhydrated Seeds (%)	Swelling Capacity (%)	Cooked Firmness (N/g)	% of Sample Retained on 22/64 Sieve	% of Sample Retained on 20/64 Sieve	% of Sample Retained on 18/64 Sieve	% of Sample Passed Through an 18/64 Sieve
Kabuli	CDC Orion*	56.3	393	111	0.0	127	23.3	49.6	45.3	4.1	1.0
	NDC160236*	64.0	441	112	0.0	125	19.3	80.0	18.1	1.8	0.1
	Royal	62.1	532	111	0.0	134	16.6	89.7	8.9	1.4	0.0
	Sierra	61.4	476	102	0.0	121	18.4	81.3	15.0	3.6	0.1

* Value from only one sample.

Water hydration capacity of chickpeas ranged from 90 to 117%, with a mean of 105% (Table 36). The water hydration capacity of chickpeas from 2022 was essentially the same as the 5-year and 10-year mean values. Only small differences in water hydration capacities were observed among cultivars. The CDC Orion and Royal cultivars both had the highest water hydration capacity (111%) while Sierra had the lowest (102%) (Table 37). In 2021, CDC Orion had the lowest (92%) water hydration capacity and demonstrates the differences that can exist depending on year of harvest and likely growing environment.

The **unhydrated seed percentage** was 0% for most chickpeas. The 0% unhydrated seeds matched the 5- and 10-year mean values of 0 and 1%, respectively (Table 36). All the cultivars had 0% mean unhydrated seed values (Table 37). No issues were observed with the rehydration of the chickpea samples. The **swelling capacity** of chickpeas ranged from 100 to 158%, with a mean value of 125% (Table 36). The mean swelling capacity value of chickpea from 2022 was significantly lower than the previous years (2019-2021) and the 5-year mean of 137%. Considering that the water hydration capacity of chickpeas in 2002 was comparable to hydration capacity of previous years, the lower swelling capacity was surprising. The immediate reason for is not known but may relate to seed structure. The Royal cultivar had the greatest mean swelling capacity (134%) while the Sierra cultivar had the lowest value (121%) among chickpeas (Table 37).

The **cooked firmness** of all chickpea ranged from 13.7 to 26.7 N/g, with a mean value of 18.6 N/g (Table 36). The mean firmness value for chickpea in 2022 was lower than the 5-year mean value (22.8 N/g). This supports chickpea were less firm after cooking compared to chickpea from previous years and that the chickpea cooking using a standard time produced chickpea with a tender structure. Among the cultivars, Royal had the lowest cooked firmness (16.6 N/g) while and CDC Orion (23.3 N/g) cultivar was the firmest (Table 37). The Royal cultivar had the highest water hydration and swelling capacities and the lowest cooked firmness supporting the inverse relationship between ability to hydrate and firmness. Similar observations were made in previous crop years.

Retention of chickpea on a series of sieves was used to determine chickpea size. The mean retentions of 79.5, 16.7, 3.6, and 1.1% on the 22/64, 20/64, 18/ 64 and passed through the 18/64-inch sieves were observed in the 2022 chickpeas, respectively (Table 36). The range of retention on the largest screen (22/64-inch sieve) was from 25.8 to 98.0%. The percentage of retention of chickpeas on the two largest screens (22/64 and 20/64-inch sieve) was approximately 96.2% in 2022 while retention values of 92, 90 and 93% were observed for the chickpea harvested in 2021, 2020 and 2019, respectively. The highest percentage retention of the samples on the 22/64-inch sieve was observed for the Royal (89.7%) while the lowest (49.6%) retention on the 22/64-inch sieve was observed in CDC Orion (Table 37).

Color quality was measured using L*, a*, and b* values and from these values a color difference was determined on chickpeas before and after soaking (Table 38). **Color quality** indicated that the lightness (i.e., L*) of the chickpeas from 2022 was less than chickpeas grown in 2021 but comparable to chickpea grown in 2020 (Table 38). The L* value for chickpea grown in 2022 was greater than the 5-year mean L* values but comparable to the 10-year mean L* value. In 2022, the a* value of 6.01 was most similar to the a* value of chickpea from 2020. Furthermore, the a* value was substantially lower for the chickpea from 2002 compared to the 5- and 10-year a* values of 7.03 and 7.46, respectively. This indicates that the chickpea had less redness compared to the long-term averages. The b* value for chickpeas from 2022 indicated similar yellowness to the chickpea from 2021, a less yellow color compared to chickpea samples that were used to determine the 5- and 10-year mean yellowness (i.e., b*), but more yellow than chickpea from 2019 (Table 38). The color of the chickpeas changed after the soaking process. Soaked chickpeas became lighter as evidenced by the higher L* values (Table 38) compared to pre-soaked chickpeas. This same trend occurred in samples from previous years. The redness (i.e., a* value) did change slightly after soaking. In contrast, chickpeas from all years became yellower (i.e., increased b* value) after soaking. The color difference between the pre- and post-soaked chickpea from 2022 was most similar to the color difference for samples from 2020 but higher than in chickpea from 2019 and lower than in chickpea that were used in the determination of the 5-year mean b* value (Table 38).

Table 38. Color quality of Kabuli chickpeas grown in the USA before and after soaking, 2018-2022 plus 5- and 10-year mean values.

Color Scale*	Mean (SD) Color Values					
	Before Soaking				5-Year Mean	10-Year Mean
	2022	2021	2020	2019		
L* (lightness)	60.57 (1.17)	61.33 (1.25)	60.47 (1.43)	55.69 (1.73)	57.19 (3.49)	61.11 (8.33)
a* (red-green)	6.01 (0.51)	6.31 (3.73)	6.07 (1.60)	5.17 (0.61)	7.03 (1.68)	7.46 (1.93)
b* (yellow-blue)	14.48 (0.67)	14.41 (2.07)	15.49 (1.37)	10.95 (0.80)	16.77 (4.64)	18.44 (5.19)
Color Scale*	After Soaking				5-Year Mean	10-Year Mean
	2022	2021	2020	2019		
L* (lightness)	60.96 (1.12)	61.79 (0.68)	61.39 (0.72)	56.16 (1.07)	58.66 (2.71)	63.07 (10.09)
a* (red-green)	6.77 (0.46)	6.69 (0.52)	6.41 (1.71)	5.21 (0.42)	8.10 (2.80)	8.59 (2.74
b* (yellow-blue)	24.40 (1.27)	24.81 (1.68)	25.78 (1.72)	16.99 (6.41)	27.38 (7.47)	31.07 (9.49)
Color Difference	9.85 (1.10)	11.23 (3.35)	10.47 (1.79)	6.41 (1.13)	13.40 (7.10)	nd

color scale L(lightness) axis – 0 is black and 100 is white; a *(red-green) axis – positive values are red, negative values are green, and zero is neutral; and b* (yellow-blue) axis – positive values are yellow, negative values are blue, and zero is neutral. nd = not determined due to test not being performed for 5 or 10 years. Color difference is the change in color after soaking.

Among cultivars, Sierra had the highest L* value (61.22) while CDC Orion had the lowest (i.e., 58.10). The Sierra cultivar had the lowest a* value among cultivars while CDC Orion had the highest (i.e., 6.80). The highest yellowness value (i.e., b*) was observed in CDC Orion (Table 39). Visual observations support the color value differences as the Royal cultivar appeared less yellow in color than other cultivars. All cultivars underwent an increase in lightness during soaking, as evidenced by the higher L* value of the soaked samples. An increased yellowness (increased b* value) was observed for all cultivars. The greatest color difference was observed in the Royal cultivar (Table 39) while the Sierra cultivar had the least color change. The Sierra cultivar also had the least color change after soaking in 2021. The change in color observed in the samples was likely due to the significant increase in yellowness (a change in b* values) during the soaking. This was supported by visual observations where the chickpea appeared more yellow after soaking.

Table 39. Mean color quality of chickpea cultivars grown in the USA, 2022.

		Mean Color Values**						
Market		Before Soaking			After Soaking			Color
Class	Cultivar	L	a	b	L	a	b	Difference
Kabuli	CDC Orion*	58.10	6.80	15.00	58.35	6.58	25.03	10.04
	NDC160236*	58.49	7.23	15.62	59.40	6.18	25.27	9.75
	Royal	59.40	6.29	14.04	60.47	7.46	25.63	10.94
	Sierra	61.22	5.74	14.40	61.38	6.61	23.87	9.55

* Value from only one sample. **color scale L (lightness) axis – 0 is black and 100 is white; a (red-green) axis – positive values are red, negative values are green, and zero is neutral; and b (yellow-blue) axis – positive values are yellow, negative values are blue, and zero is neutral. Color difference is the change in color after soaking.

Pasting properties (Tables 40-41)

Peak and hot paste viscosities of chickpeas grown in 2022 were generally lower than peak and hot paste viscosities from previous years, including the mean 5- and 10-year mean peak and hot paste viscosity values (Table 40). The cold paste viscosity of the 2022 chickpea crop was most similar to the chickpeas from 2018 and 2020. The mean 5- and 10-year cold paste viscosity values were higher than the values for the chickpeas harvested in 2022. The peak time was slightly longer for samples from 2022 compared to other crop years but was lower than the mean 10-year value. The pasting temperature was higher for the chickpeas from 2022, except 2020, compared to chickpeas from other years and to the 5-year mean pasting temperature. Among chickpeas, Sierra had the lowest peak viscosity (121 RVU) while Royal (139 RVU) had the highest peak viscosity (Table 41). These same cultivars had the lowest and highest hot paste viscosities. The lowest and highest cold paste viscosities were observed in CDC Orion (161 RVU) and Royal (216 RVU), respectively. Pasting temperature was lowest (77.0 °C) and highest (77.6 °C) for Royal and CDC Orion cultivars, respectively. The RVA gel firmness ranged from 154 to 367 g with a mean of 272 g (Table 40). The Royal cultivar had the firmest (i.e., highest value) RVA gel texture while CDC Orion produced a gel with the least firmness (Table 41).

Table 40. Starch characteristics of Kabuli chickpeas grown in the USA, 2018-2022 plus 5- and 10 year mean values.

Starch Characteristic	Year 2022		2021	2020	2019	2018	5-year	10-year
	Range	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Peak Viscosity (RVU)	98-155	125 (14)	129 (20)	136 (16)	136 (18)	131 (15)	133 (3)	137 (16)
Hot Paste Viscosity (RVU)	96-146	121 (12)	123 (18)	128 (13)	131 (16)	125 (12)	128 (3)	130 (12)
Breakdown (RVU)	1-21	4 (4)	10 (1)	7 (5)	5 (4)	6 (6)	5 (2)	8 (6)
Cold Paste Viscosity (RVU	147-252	189 (28)	200 (53)	186 (23)	198 (30)	187 (29)	196 (6)	203 (35)
Setback (RVU)	35-106	68 (17)	77 (36)	58 (15)	68 (18)	62 (20)	68 (7)	68 (30)
Peak Time (Minute)	5.13-7.00	6.53 (0.58)	6.47 (0.63)	6.12 (0.56)	6.33 (0.57)	6.06 (0.65)	6.34 (0.17)	6.96 (1.67)
Pasting Temperature (°C)	74.4-80.4	77.1 (1.4)	76.9 (1.2)	78.0 (1.4)	75.6 (1.6)	75.8 (1.9)	75.2 (1.13)	nd
RVA Gel Firmness (g)	154-367	272 (54)	*	*	*	*	nd	nd

*not previously measured; nd = not determined due to test not being performed for 5 or 10 years.

Table 41. Mean starch characteristics of chickpea cultivars grown in the USA, 2022.

Market Class	Cultivar	Peak Viscosity (RVU)	Hot Paste Viscosity (RVU)	Breakdown (RVU)	Cold Paste Viscosity (RVU)	Setback (RVU)	Peak Time (Min)	Pasting Temperature (°C)	RVA Gel Firmness (g)
Kabuli	CDC Orion*	130	126	4	161	35	6.20	77.6	213
	NDC160236*	98	96	2	158	62	5.67	75.1	316
	Royal	139	133	6	216	83	5.83	77.0	319
	Sierra	121	119	2	184	66	6.89	77.4	258

* Value from only one sample.

Functional properties (Tables 42-43)

Functionality property evaluation is new in 2022. These tests include emulsion activity and stability, foaming capacity and stability, water holding capacity and oil holding capacity. The emulsion activity and stability for all chickpea samples ranged from 56-60% and 54-60% (Table 42). However, no differences in emulsion activity and stability were observed based on cultivar (Table 43). In contrast to emulsion activity, foaming capacity varied to a greater extent (123-203%). Differences in foaming capacity among different cultivars of chickpeas was observed (Table 43), CDC Orion had a mean foaming capacity that was approximately 30-50 percentage points higher than the mean foaming capacity of other cultivars. In contrast, the CDC Orion had a slightly lower foam stability than other cultivars. The CDC Orion cultivar had higher water holding capacity compared to the other cultivars, which may be responsible for the higher foaming capacity. Minimal differences in the oil holding capacities were observed in the chickpeas from 2022.

Table 42. Functional properties of Kabuli chickpeas grown in the USA, 2022.

Functional Properties	Year 2022 Range	Mean (SD)
Emulsion Activity (%)	55-60	57 (1)
Emulsion Stability (%)	54-60	58 (1)
Foaming Capacity (%)	123-203	164 (20)
Foam Stability (%)	72-92	85 (5)
Water Holding Capacity (g/g)	0.88-1.42	1.01 (0.11)
Oil Holding Capacity (g/g)	0.10-0.43	0.25 (0.09)

Table 43. Functional properties of chickpea cultivars grown in the USA, 2022.

Market Class	Cultivar	Emulsion Activity (%)	Emulsion Stability (%)	Foaming Capacity (%)	Foam Stability (%)	Water Holding Capacity (g/g)	Oil Holding Capacity (g/g)
Kabuli	CDC Orion	57	57	203	77	1.42	0.29
	NDC16023	59	59	190	72	1.03	0.24
	Royal	57	58	173	86	0.92	0.26
	Sierra	57	58	157	86	1.00	0.24

*Only one sample of cultivar tested

Canning Quality Results

Canning quality was completed only on pea and chickpea. The quality evaluation includes hydration capacity, swelling capacity, canned firmness, and color evaluation. Hydration capacity and swelling capacity were completed following the soak test method. The only difference was that the hydration and swelling capacity was measured on a canned pea or chickpea.

Peas (Tables 44-46)

The mean **water hydration capacity** of canned peas was 231% for all peas (Table 44). This value is higher than the water hydration capacity of peas from the most recent crop years except 2019. The water hydration capacity of the pea from 2022 was higher than the 5-year mean water hydration value. Water hydration capacities ranged from 176 to 259 for all peas in 2022 which is similar to data from 2019 for all peas. A difference in water hydration capacity between the green (221%) and yellow (219%) market classes was observed. Furthermore, Winter pea (248%) had the highest water hydration capacities among market classes (Table 44). Overall, the data indicates more water uptake of the peas from 2022 compared to previous years except 2019. In green peas, all commercial cultivars had comparable water hydration capacity at 213 to 2016 (Table 45). In yellow cultivars, AAC Julius and Pizzaz had the highest (254 and 248%, respectively) mean water hydration capacities while the Salamanca had the lowest (176%) value (Table 45). The winter pea cultivar Blaze had a similar water hydration capacity (248%) compared to the green peas. The results of the soak test did not directly translate into similar results as in the canning water hydration in the context of an order for the cultivars.

Table 44. Mean physical parameters of canned dry pea grown in 2018-2021 plus the 5-year mean value.

Physical Parameter	2022 Range	2022 Mean (SD)	2021 Mean (SD)	2020 Mean (SD)	2019 Mean (SD)	2018 Mean (SD)	5-year Mean (SD)
All Pea Samples							
Water Hydration Capacity (%)	176-259	231 (24)	143 (28)	199 (30)	260 (46)	214 (36)	205 (42)
Swelling Capacity (%)	125-188	165 (18)	181 (12)	205 (19)	204 (24)	214 (18)	202 (12)
Canned Firmness (N/g)	3.4-9.7	5.8 (2.0)	17.8 (7.6)	7.3 (3.0)	5.9 (2.3)	4.7 (1.3)	8.3 (5.4)
Green Pea Samples							
Water Hydration Capacity (%)	194-253	221 (20)	137 (21)	198 (32)	254 (45)	193 (26)	199 (42)
Swelling Capacity (%)	133-173	156 (14)	180 (11)	204 (20)	200 (20)	206 (30)	198 (10)
Canned Firmness (N/g)	5.1-8.1	6.6 (1.0)	19.0 (6.7)	7.2 (3.1)	6.35 (2.31)	5.2 (1.0)	8.5 (5.9)
Yellow Pea Samples							
Water Hydration Capacity (%)	176-254	219 (30)	162 (29)	199 (28)	265 (46)	227 (36)	218 (37)
Swelling Capacity (%)	125-173	152 (17)	182 (14)	206 (20)	206 (25)	216 (17)	203 (13)
Canned Firmness (N/g)	4.6-9.7	7.4 (1.9)	12.6 (6.7)	7.4 (3.0)	5.73 (2.21)	4.4 (1.4)	7.1 (3.2)
Winter Pea Samples							
Water Hydration Capacity (%)	237-259	248 (7)	123 (8)	217 (23)	214 (41)	*	nd
Swelling Capacity (%)	175-188	181 (5)	180 (12)	211 (6)	204 (16)	*	nd
Canned Firmness (N/g)	3.4-4.5	3.9 (0.4)	23.7 (3.6)	7.3 (2.4)	7.39 (4.28)	*	nd

*Canning quality not determined on winter pea prior to 2019. nd = not determined due to test not being performed for 5 years.

The **swelling capacity** is the amount of swelling that occurred during rehydration of the dry pea and the canning operation. The swelling capacity of all peas ranged from 125 to 188%, with a mean value of 165% (Table 44). These values were lower than the swelling capacity of peas from the 2018-2021 crop years, including the 5-year mean value. In contrast to water hydration capacity, mean swelling capacity values for the peas from 2022 were lower than previous years. The green and yellow peas had similar mean swelling capacities (156 and 152%, respectively) while winter peas had higher (181%) swelling capacity. The green pea cultivars Banner and Shamrock had the highest (173%) and lowest (145%) mean swelling capacities, respectively. In yellow cultivars, Pizzaz had the highest (173%) mean swelling capacity while the Salamanca cultivar had the lowest swelling capacity at 125% (Table 45). The mean swelling capacity of Blaze was 181%.

Table 45. Mean physical and color parameters of canned dry pea cultivars grown in 2022.

Market Class	Cultivar	Hydration Capacity (%)	Swelling Capacity (%)	Canned Firmness (N/g)	Mean Color Values* Before Soaking L*	a*	b*	After Soaking L*	a*	b*	Color Difference
Green	Banner**	214	173	6.2	59.60	-1.28	10.23	50.04	0.54	16.04	11.43
	Ginny 2**	216	165	6.2	59.10	-2.16	8.93	46.21	0.78	12.29	13.65
	ND Victory**	217	144	8.1	59.16	-2.61	11.57	46.95	0.16	13.64	12.68
	NDP150412G**	253	161	5.1	59.63	-2.04	10.08	48.88	0.74	14.67	12.02
	Shamrock	213	145	6.9	56.65	-1.63	11.38	47.31	-0.02	14.01	9.86
Yellow	AAC Chrome**	207	143	6.8	63.34	5.33	15.64	55.87	5.36	23.75	11.04
	AAC Julius**	254	166	5.9	62.79	6.12	15.99	58.60	4.06	26.90	11.88
	NDP140510Y**	202	154	9.2	64.53	4.37	16.11	54.56	5.20	23.31	12.39
	NDP150231Y**	224	153	8.2	62.08	3.53	15.50	51.30	2.69	18.03	11.86
	Pizzaz**	248	173	4.6	63.72	5.35	15.60	56.78	5.76	24.55	11.34
	Salamanca**	176	125	9.7	65.43	4.74	14.90	53.08	6.78	21.30	14.07
Winter	Blaze**	248	181	3.9	60.28	2.01	13.36	56.32	2.81	24.32	11.77

*color scale: L (lightness) axis – 0 is black and 100 is white; a (red-green) axis – positive values are red, negative values are green, and zero is neutral; and b (yellow-blue) axis – positive values are yellow, negative values are blue, and zero is neutral.
**Only one sample of cultivar tested.

Unlike 2021, the **canned firmness** values of peas were significantly lower than the cooked firmness values of soaked peas. For comparison, the mean cooked firmness for all peas from 2022 was 22.1 N/g (Table 7) while for canned pea, in 2022, the mean firmness value was 5.8 N/g (Table 44). This observation is typical of what is expected and demonstrates the unusual nature of the peas from 2021. The mean canned firmness of the peas from 2022 most closely matched the mean canned firmness of peas from 2019. The mean canned firmness of peas from 2022 was less than that of the 5-year mean canned firmness value (Table 44). In general, winter peas had the lowest (3.9 N/g) and yellow peas the highest (7.4 N/g) canned firmness. For both the green and yellow pea, the mean firmness values were greater than the values for the 5-year mean suggesting slightly firmer peas, but significantly less firm than the peas from 2021. Banner and Ginny 2 cultivars were the least firm (6.2 N/g) among the green peas while Shamrock (6.9 N/g) was the firmest (Table 45). In yellow peas, Pizzaz had the least (4.6 N/g) firmness while Salamanca had the greatest (9.7 N/g) firmness among yellow cultivars. Salamanca also had the greatest firmness for yellow peas in 2021.

The color of the dry pea changed after the canning process. The color difference fell between 11.77 and 12.51 for all peas with winter having the lowest color difference. The lower color difference of yellow winter pea in 2021 suggest that the winter pea color is impacted less by processing compared to green and yellow pea. Except for the 2019 and 2021 production years, the color difference in difference between the dry and canned peas was less than previous crop years (Table 46). The lightness decreased during canning for all market classes. In the soak test, only the green cultivars darkened upon soaking (Table 10). The green peas tended to become less green and more yellow during canning as evidenced by the a* and b* values, respectively. The yellow peas and yellow winter peas became darker and more yellow after canning. The greatest color difference was observed in the Ginny 2 (green) and Salamanca (yellow) cultivars after canning (Table 45) while the Shamrock (green) and AAC Chrome (yellow) cultivars had the lowest color difference. Shamrock also had the lowest color change in the 2019, 2020, and 2021 canning evaluation.

Table 46. Mean color characteristics of canned dry pea grown in 2018-2022 plus the 5-year mean value.

	Mean (SD) Color Values*						
	Before Canning			After Canning			
Sample**	L*	a*	b*	L*	a*	b*	Color Difference
Green Pea Samples							
2022	58.25 (2.03)	-2.08 (0.52)	10.11 (0.65)	50.05 (1.41)	0.13 (1.05)	18.92 (1.43)	12.51 (1.33)
2021	57.33 (2.35)	-2.30 (1.01)	10.45 (0.74)	48.03 (1.38)	0.32 (0.41)	14.50 (1.26)	10.67 (1.67)
2020	58.60 (2.46)	-1.87 (0.74)	9.46 (0.78)	51.62 (1.55)	-0.35 (1.37)	19.59 (2.06)	12.88 (1.65)
2019	53.40 (1.59)	-1.88 (0.73)	7.00 (0.60)	45.33 (2.02)	-0.63 (0.58)	12.41 (1.30)	10.04 (1.54)
2018	51.68 (3.57)	-1.92 (0.77)	14.15 (1.49)	46.02 (2.61)	2.38 (0.54)	30.58 (2.12)	18.16 (1.93)
5-Year Mean	54.77 (3.02)	-1.85 (0.37)	11.24 (3.37)	47.44 (2.54)	0.83 (1.48)	21.25 (8.31)	13.67 (3.59)
Yellow Pea Samples							
2022	63.65 (1.20)	4.91 (0.90)	15.62 (0.43)	55.03 (2.62)	4.97 (1.42)	22.97 (3.03)	12.10 (1.07)
2021	64.29 (1.26)	5.30 (0.39)	15.04 (0.78)	55.91 (1.54)	7.04 (0.98)	23.14 (1.44)	11.95 (1.09)
2020	63.47 (2.66)	4.99 (0.69)	14.57 (1.25)	56.46 (4.86)	4.14 (1.43)	24.49 (2.24)	13.08 (4.63)
2019	58.63 (1.72)	4.10 (0.54)	11.39 (0.71)	51.06 (1.58)	3.95 (0.81)	15.65 (1.29)	8.94 (1.98)
2018	58.76 (2.39)	6.91 (0.99)	17.33 (1.53)	56.91 (3.94)	6.59 (1.13)	30.96 (3.65)	13.30 (4.68)
5-Year Mean	60.73 (2.89)	5.60 (1.19)	15.72 (3.32)	55.01 (2.36)	5.59 (1.44)	24.78 (6.08)	11.66 (1.77)
Green Winter Pea Samples#							
2022	nd	nd	nd	nd	nd	nd	nd
2021	53.88 (0.34)	-2.54 (0.23)	8.49 (0.51)	45.06 (1.12)	0.24 (0.23)	12.99 (0.62)	10.35 (1.39)
2020	55.31 (1.11)	-1.84 (0.61)	8.93 (0.67)	51.10 (0.31)	-2.89 (0.19)	21.77 (1.30)	13.56 (0.92)
2019	49.36 (0.53)	-2.25 (0.04)	6.09 (0.03)	44.52 (0.41)	-0.88 (0.53)	11.57 (1.12)	7.47 (0.63)
Yellow Winter Pea Samples#							
2022	60.28 (0.57)	2.01 (0.57)	13.36 (0.44)	56.32 (0.53)	2.81 (0.67)	24.32 (1.44)	11.77 (1.33)
2021	59.71 (3.01)	1.96 (1.87)	13.91 (0.88)	51.37 (0.25)	3.43 (0.81)	19.58 (0.16)	10.67 (1.43)
2020	60.29 (0.83)	2.52 (0.32)	14.28 (0.49)	57.42 (1.49)	3.82 (0.28)	26.78 (3.20)	13.04 (2.95)
2019	nd	nd	nd	nd	nd	nd	nd

color scale: L (lightness) axis – 0 is black and 100 is white; a* (red-green) axis – positive values are red, negative values are green, and zero is neutral; and b* (yellow-blue) axis – positive values are yellow, negative values are blue, and zero is neutral. **Includes all pea samples or separated into market class. #Canning quality not determined on winter pea prior to 2019. nd= no sample evaluated within the green or yellow winter market class.

Chickpeas (Tables 47-48)

The mean **water hydration capacity** of canned chickpea was 163% with a range from 143 to 178%. These values were comparable to the canned chickpeas from 2019 and 2020 (Table 47). The mean water hydration capacity of canned chickpea from 2022 was higher than that observed for the 5-year mean (140%). The CDC Orion cultivar had the highest water hydration capacity at 169% while Royal had the lowest at 159% (Table 48). The **swelling capacity** is the amount of swelling that occurred during rehydration of the dry chickpea and the canning operation. The swelling capacity of all chickpeas ranged from 111 to 166%, with a mean value of 124%. The Sierra cultivar had the lowest swelling capacity at 123% while Royal had the highest at 127% (Table 48).

Table 47. Mean physical and color parameters of canned chickpea grown in 2018-2022 plus the 5-year mean value.

				Mean (SD) Color Values*						
				Before Soaking			After Soaking			
Year	Hydration Capacity (%)	Swelling Capacity (%)	Canned Firmness (N/g)	L*	a*	b*	L*	a*	b*	Color Difference
2022	163 (10)	124 (10)	6.6 (0.6)	61.36 (1.05)	6.16 (0.54)	14.77 (0.68)	53.88 (1.01)	5.53 (0.45)	17.68 (1.05)	8.24 (1.17)
2021	128 (9)	163 (13)	14.8 (1.4)	61.38 (1.11)	5.85 (0.56)	14.35 (0.69)	51.79 (0.80)	6.42 (0.53)	15.66 (0.90)	9.81 (1.17)
2020	162 (9)	177 (12)	8.0 (0.9)	60.34 (1.39)	5.89 (1.76)	15.66 (1.40)	53.48 (1.99)	5.00 (1.54)	19.19 (2.20)	8.39 (2.02)
2019	164 (12)	192 (11)	6.7 (0.9)	55.99 (1.64)	5.27 (0.63)	10.88 (0.82)	46.84 (1.03)	4.50 (0.72)	11.66 (1.08)	9.48 (1.84)
2018	125 (11)	173 (23)	9.9 (1.8)	53.45 (3.13)	9.06 (1.14)	21.74 (1.67)	47.39 (2.23)	8.62 (3.57)	26.81 (2.32)	9.29 (4.20)
5-Year Mean	140 (21)	175 (11)	10.0 (3.1)	55.24 (4.05)	6.92 (1.74)	16.78 (4.66)	49.07 (3.35)	6.49 (1.78)	19.52 (6.17)	9.49 (0.77)
2022 (Data Range)	143-178	111-166	5.8-8.1	59.63-63.25	5.20-7.34	13.26-16.30	52.19-57.01	4.77-6.52	15.77-20.19	5.72-11.17

*color scale: L (lightness) axis – 0 is black and 100 is white; a (red-green) axis – positive values are red, negative values are green, and zero is neutral; and b (yellow-blue) axis – positive values are yellow, negative values are blue, and zero is neutral.

Table 48. Mean physical and color parameters of canned dry chickpea cultivars grown in 2022.

				Mean Color Values*						
				Before Soaking			After Soaking			
Cultivar	Hydration Capacity (%)	Swelling Capacity (%)	Canned Firmness (N/g)	L*	a*	b*	L*	a*	b*	Color Difference
CDC Orion**	169	125	7.1	59.85	7.09	16.08	53.46	5.91	18.86	7.07
NDC160236**	178	123	7.3	60.00	7.34	16.24	54.23	6.52	17.79	6.08
Royal	159	127	6.6	60.30	6.56	14.38	53.83	5.38	17.71	7.55
Sierra	162	123	6.6	61.95	5.85	14.63	53.92	5.49	17.44	8.67

*color scale: L (lightness) axis – 0 is black and 100 is white; a (red-green) axis – positive values are red, negative values are green, and zero is neutral; and b (yellow-blue) axis – positive values are yellow, negative values are blue, and zero is neutral. **Only one sample of cultivar tested.

The **canned firmness** values of chickpeas were lower than the cooked firmness values of soaked chickpeas. The mean canned firmness value of all chickpeas was 6.6 N/g (Table 47). In comparison, the mean cooked firmness for all chickpeas was 18.6 N/g (Table 36). As expected, the canned chickpeas were less firm than the cooked chickpeas. Sierra and Royal had the least firmness while CDC Orion chickpeas were the firmest (Table 48). The color of the chickpeas changed after the canning process. The color difference fell between 5.72 and 11.17, with a mean value of 8.24 for all chickpeas (Table 47). The color difference was comparable to the canned chickpeas from the 2020 crop year. A higher color difference was observed in soaked (9.85) chickpeas compared to canned (8.24) chickpeas. The L* or lightness decreased during canning (Table 47). In contrast, the L* values of chickpeas generally increased in the soak test. The greatest color difference after canning was observed in the Sierra cultivar while CDC Orion had the least color change (Table 48).

Research Corner

The project below was an outcome of research completed by Abdulmalik Albutuwaybah, Prakriti Dhakal, Atanu Biswas, and Clifford Hall. Funding used to support this effort was provided by the Northern Pulse Growers Association, U.S. Dry Pea and Lentil Council, and the USDA-ARS under the Pulse Crop Health Initiative (PCHI) agreement 58-3060-9-049. All information provided below is the sole opinion of the researchers. This research was undertaken to determine the impacts of storage on functional properties of peas. Yellow dry peas are high in protein, starch, and fiber and can be used to make specialty products like cookies. Seed storage is critical to providing food throughout the year and maintaining not only nutrients, but also functional properties. The impact of a 360-day storage under different conditions (temperature and humidity) on the chemical and functional properties of yellow pea was investigated. The study used yellow peas that were stored for one year at room temperature (RT) and relative humidity of <40% (RT-40), 55% (RT-55), 65% (RT-65), and 75% (RT-75). Samples were also stored at 50°C with relative humidity of <40% (50-40), 50%(50-50), 58% (50-58), 65% (50-65), 75% (50-75), and 84% (50-84), and a control sample stored at -40°C. The goal of using these temperatures was to evaluate a typical storage (room temperature) and an extreme temperature (50°C) that may be encountered during the storage of pulses. Proximate analysis (protein, total starch, resistant starch), functional properties (foaming and emulsion capacity and stability), shelf-life determination of the cookies (texture analysis), and sensory evaluation were evaluated on flours and cookies prepared from stored peas. All data were statistically analyzed using ANOVA (p<0.05) and mean comparisons made by LSD.

Compared to room temperature (RT) and the control (frozen samples), the moisture and starch contents were generally lower for peas stored at 50°C (Table 1). A dramatic reduction can be seen in the starch content suggesting that starch was degrading during the high temperature storage. Lower resistant starch values were observed for samples stored at RT and 55% humidity (RH) and 50°C at 75% RH compared to the control. No differences in protein content were observed among samples. Foaming capacity of peas at both temperatures and RH of 65% or less had the highest foaming capacity (Figure 1). Significantly lower foaming capacity was observed for the flours obtained from seed that were stored at 50°C under 75 to 84% RH conditions. Peas from the RT with 25–40% RH conditions had a high emulsion capacity, while peas from 50°C with 50% and 58% RH had the lowest values. However, flours from peas stored at 50°C and 75% RH had the highest emulsion stability. Overall, only small differences were observed in the cookie physical properties. Many of the cookie parameters measured were not significantly different. However, the texture of the cookies on day 1 was noticeably different from other days. Cookies made with flour from peas stored at 50°C and <40% RH had the highest hardness value. On days 3, 6, and 14, fracturability was significant, where cookies made with peas stored at RT had lower fracturabilty compared to cookies made with peas stored at 50°C and control samples. The cookies of RT with 55% humidity had the highest flavor and overall acceptability among tested cookies. High temperature and high RH storage had the most significant impact on chemical composition and functional properties. While most storage negatively impacted functionality, foaming was improved for the stored samples compared to the control. The application of stored peas in cookies provided support that storage impacted parameters evaluated. The intended outcome of this research report was to provide an overview of the project and results. More details will follow in a published manuscript.

Table 1. Proximate composition of flour from pea stored 360 days under diverse storage conditions.

	Proximate composition (Mean (Standard Deviation)*			
	Moisture (%)	**Total Starch (%)**	**Resistant Starch (%)**	**Protein (%)**
RT<40	10.41 (0.21)c	43.56 (1.15)a	16.55 (0.19)a	18.58 (0.28)a
RT55	11.26 (0.27)b	44.65 (0.86)a	14.52 (0.27)b	18.63 (0.38)a
RT65	10.79 (0.07)bc	42.9 (0.46)b	15.35 (0.12)a	19.02 (0.16)a
RT75	11.11 (0.57)b	43.84 (0.52)a	15.98 (1.17)a	18.92 (0.36)a
Control	11.96 (0.06)a	41.96 (0.98)b	16.05 (1.49)a	18.72 (0.24)a
50-40	5.66 (0.20)h	25.27 (1.33)c	18.69 (0.97)c	19.04 (0.45)a
50-50	6.53 (0.17)g	25.29 (0.58)c	18.58 (0.73)c	18.98 (0.48)a
50-58	6.84 (0.10)g	25.34 (0.72)c	17.82 (0.55)a	19.22 (1.34)a
50-65	8.56 (0.23)f	24.7 (0.06)c	15.78 (1.48)a	19.17 (0.52)a
50-75	11.17 (0.16)b	24.15 (0.31)c	13.84 (0.63)b	18.97 (0.51)a
50-84	9.24 (0.17)e	25.1 (0.54)c	15.32 (0.047)a	19.2 (0.28)a

*Values followed by the same letter indicates that the samples are not significantly different (p>0.05) from one another.

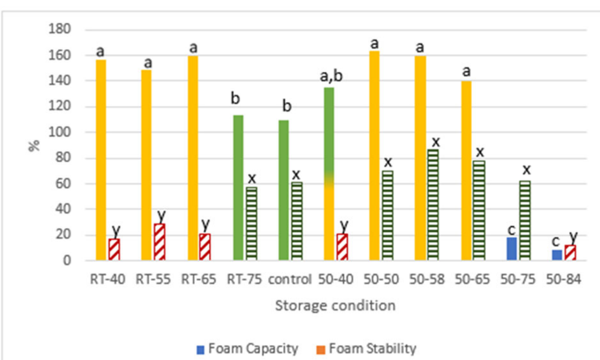


Figure 1. Foaming capacity (solids bars) and stability (pattern bars) of flour obtained from stored peas. Bars with diffferent letters indicates significant differences (p≤0.05) between treatment within property evaluated.

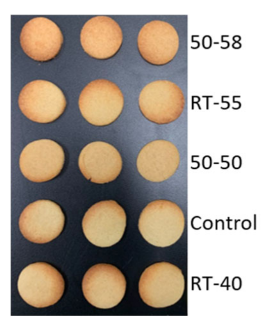


Figure 2. Cookies made with pulses that were stored under various temperature and relative humidities.

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