2020
U.S. Pulse Quality Survey

South Dakota State University
South Dakota Agricultural Experiment Station

USA Dry Pea & Lentil Council

Northern Pulse Growers Association

Contents

2020 Overview and Author's Comments

Summary Points

1. The 2020 pulse quality report represents the 13th variation of a pulse quality evaluation started by the Northern Crops Institute in 2008.
2. Data from approximately 353 samples received from major US pulse growing regions were evaluated.
3. In general, proximate composition tended to match the 2017 and 2018 harvest years. However, physical quality traits evaluated did not consistently match the results of previous years.
4. A canning quality evaluation was included for the fourth time in this report for pea and chickpea. The pulses evaluated tended to be firmer and had lower canning water hydration capacity, but similar swelling capacity compared to previous years.
5. A chickpea size distribution was included for the second time. A sieve analysis was not only effective in differentiating small and large chickpea, but also intermediate sized chickpea based on retention on various sieves. The 2020 samples tended to be slightly smaller than chickpea from 2019.
6. In 2020, a Desi chickpea was included in the evaluation.

This report provides a summary of the 2020 pulse crop quality for dry pea, lentil and chickpea grown commercially in the USA. In 2020, a total of 353 pulse samples were collected from the major US pulse growing regions. This number represents the most samples evaluated since the inception of the survey. The seeds evaluated included 194 dry pea, 91 lentil and 68 chickpea, which were acquired from pulses growers and industry representatives in pulse growing areas in Idaho, Montana, North Dakota, South Dakota, Oregon and Washington.

According to the USDA National Agricultural Statistics Service, pulse harvested acreage and estimated total production for 2020 was 1.7 million and 1.5 Million MT, respectively. Pea acreage was lower in 2020 compared to 2019 but higher than acreage in 2018. As with pea, chickpea production was down in 2020. In contrast, lentil acres were up by over 50,000.

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.

Results from the proximate (i.e., moisture, protein, etc.) composition analyses indicate that results aligned most closes with the 2017 and 2018 crop year for dry pea, the 2018 crop year for the lentil and chickpea. The difference might be related to the more diverse pool of samples from different growing locations. The 353 pulse samples evaluated in 2020 were the most diverse based on the number of different cultivars tested.

In general, pea, lentil, and chickpea from 2020 had lower moisture contents compared pulses from previous crop years. All pulses had moisture contents lower than the 5-year mean moisture values. In contrast, the total starch contents of all three pulses were higher than the five-year. The total starch percentages in lentils from 2020 was comparable to the lentils harvested in 2017 and 2018 while total starch in chickpea grown in 2020 was comparable to chickpea from 2015 and 2018. The protein percentage of peas from 2020 most closely matched those from the 2017 and 2018 harvest years. Lentils from 2020 had protein contents similar to lentils from 2018 and were 1.4 percentage point higher than the 5-year mean protein content. Protein content in lentils match those values from 2017 and 2018 while protein in chickpea matched values from 2018. The fat contents of the pulses evaluated were within ranges reported in the literature.

However, the fat contents of all pulses from 2020 were comparable to those from 2019. The yellow and green dry pea composition was similar. The yellow peas tended to have lower protein and starch percentages compared to the green peas. Winter pea samples had protein contents similar to yellow pea. In contrast, the starch content more closely matched green peas. Marrowfat peas had a protein identical to green peas while the starch content matched the yellow peas. Only small differences in the proximate composition were observed between the three lentil market classes. The green and Spanish brown lentils had similar protein contents while the red lentils had higher protein than the other two classes. In contrast, green lentils had a higher starch percentage than both the red and Spanish brown lentils. In 2020, one sample of Desi chickpea was analyzed and compared to the Kabuli chickpeas. The Desi chickpea evaluated tended to have a lower protein and starch contents than the Kabuli. However, the moisture and fat contents were higher. Additional Desi samples would be needed to support the observed data representing the proximate composition.

The physical parameters such as water hydration capacity, test weight, and color analysis of the 2020 had varying result compared to previous pulse crops. Overall, the test weight of dry peas and chickpeas were approximately that of the 5-year average while lentils were approximately 2 lbs/bu higher than the 5-year mean. The 1000 seed weight was higher for peas and lentils and lower in chickpea compared to the 5-year mean. The water hydration capacities were lower than the 5-year mean for pea and lentil and but slightly higher than the 5-year mean for chickpea. Swelling capacity of chickpea from 2020 was significantly higher than the 5-year mean swelling capacity, suggesting that the chickpea from 2020 tended to swell more than chickpea from previous years. A size distribution analysis of chickpea was conducted for the second time in 2020. The percentage of seed being retained on a series of sieves provide a means to differentiate size. As in 2019, Nash and Dylan chickpea cultivars had the highest percentage of seeds retained a 22/64-inch sieve in 2020. This high percentage supports these as being large chickpea. In contrast, only 1 and 13.6% of the Kasin and Bronic seed were retain on the 22/64-inch sieve, respectively, supporting that these are small chickpeas.

The color of the peas in 2020 were lighter than pea from other harvest years. The lighter color was supported by higher lightness (L*) values. The color difference values of dry peas from 2020 were generally lower than peas from other crop years except 2019. The color tended to be lighter for all lentils regardless of lentil color. However, the color values were similar to the lentils from 2015. The 2020 chickpea crop had slightly higher lightness values compared to previous crop years except 2015. However, the yellowness values (b* value) were significantly lower than chickpea grown in other years except 2019.

The starch pasting properties of peas closely matched those of the peas from 2015, 2017, and 2018. The paste that resulted from the 2020 pea flour was less viscous than the paste from the pea flour from the 2016 crop year but was comparable to peas from other years. The peas from the yellow market class had viscosity properties that were different than from yellow peas from other years. However, the pasting characteristics of green peas from 2020 closely aligned with pea from 2017 and 2018. The pasting properties of the lentil flour from the 2020 samples were most like the pasting properties of lentils from 2018. Differences in pasting properties were found between lentil cultivars. The pasting characteristics of all market classes were similar to the 5-year mean viscosity values for their respective market class. Pasting properties of chickpea from 2020 mirrored the pasting properties of the chickpea from 2018 and 2019.

The canning evaluation was completed for a fourth time since the survey inception. Overall, the canning quality of pea and chickpea from 2020 differed from previous evaluations. Water hydration capacity, and swelling capacity of the canned pea in 2020 were lower than peas from 2018 and 2019. In contrast, canning firmness was lower than in 2018 but higher than peas from 2019. Chickpea from 2020 had hydration capacity and swelling capacity similar to canned chickpea from 2019. The mean canning firmness of chickpea from 2020 was only slightly higher than the mean canning firmness of chickpea from 2019. However, lower canning firmness was observed in chickpea from 2020 compared to the samples from 2018.

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.
clifford.hall@sdstate.edu

Pulse Production

The Northern Plains region and Pacific Northwest are the largest pulse producing area within the USA. US pulse harvested acreage in 2020 was 1,684,200 (USDA 2020; Table1), which was approximately 202 thousand less acres than in 2019. Total US pulse production (Metric Tons (MT) in 2020 is estimated to be 1,469,559, which is up slightly from the 1,460,378 produced in 2018, but down from the 1,725,806 from 2019. The conditions affecting the pulse growing regions likely contributed to the lower production compared to 2019. Pulse production was higher than the 1,304,132 MT produced in 2017.

The UDSA (2020) estimated that the dry pea acreage was 949,000, which was down from the 1,052,000 in 2019 (Table 1). Pea production (941,571 MT) was less than the 2016 and 2019 production of 1,228,282 MT and 1,135,229 MT, respectively (Table1).

Lentil acreage was 486,000 in 2020 and is slightly higher than the 431,000 from 2019 (USDA; Table 1). Lentil production (330,418 MT) in 2020 was higher than the 273,723 MT in 2019 but lower than 398,572 MT in 2018, 380,905 MT in 2017 and 564,087 MT in 2016.

Chickpea harvested acres in 2020 (249,200) was comparable to the acres (277,500) harvested in 2016 but lower than the 404,000 in 2019, 651,300 acres in 2018, and 476,300 acres in 2017 (USDA 2020). Production was estimated at 197,570 MT, which is lower than the 316,854 MT in 2019, 425,870 MT in 2018 and 234 thousand MT in 2017. The production was higher than the 135,016 MT produced in 2016.

The increased production of the pulses supports increased yields per acres. The yield for dry pea was 1,953 lbs/acre in 2020. This value is slightly lower than the 2,124 lbs/acre obtained in 2019. The yield is comparable to the 1,972 lbs/acre obtained in 2018 and higher than the 1,350 lbs/acre obtained in 2017. Lentil yield (1,338 lbs/acre) in 2020 was significantly higher than the 1,250, 1,171 and 732 lbs/acre yields from 2019, 2018 and 2017, respectively. Chickpea yield was 1561 lbs/acre in 2020, which was higher than the 1,544, 1511 and 1,155 lbs/acre in 2019, 2018 and 2017, respectively.

Table 1. United states pulses acreage and production summary for 2016-2020.

	2020		2019		2018		2017		2016	
Crop	Acreage*	Production**	Acreage*	Production**	Acreage	Production**	Acreage	Production**	Acreage	Production**
Dry Peas	949,000	941,571	1,052,000	1,135,229	836,400	635,936	1,108,900	648,251	1,334,800	1,228,282
Lentil	486,000	330,418	431,000	273,723	758,000	398,572	957,000	380,905	917,000	564,087
Chickpea	249,200	197,570	404,000	316,854	651,300	425,870	476,300	238,975	277,500	135016
Total	1,684,200	1,469,559	1,887,000	1,725,806	2,245,700	1,460,378	2,542,200	1,304,132	2,529,300	1,927,385

*Acreage = Acres Harvested - USDA NASS (2020); **Production = Metric Tons - USDA NASS (2020)

Laboratory Methods Used to Measure Pulse Quality

Where applicable, standard methods were followed for the determination of each pulse quality attribute in 2020 (Table 2). For most analyses, data is provided on data collected between 2015 and 2020. The data is report as a range, mean and standard deviation (SD) for the 2020 harvest year while preceding years were provided as a means plus SD. Data on cultivars was reported only for the 2020 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 discussion 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 dramatically 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, pea and lentil 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 mineral 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 (GAC 2100) 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. The 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.

Table 2. Quality attribute, analytical method, and remarks for analyses conducted for the 2020 pulse quality survey.

Quality Attribute	Method	Remarks
1. Moisture (%)	AACC Approved Method 44-15A	Indicator of post-harvest stability, milling yield and general processing requirements.
2. Protein (%)	AACC Approved Method 46-30	Indicator of nutritional quality and amount of protein available for recovery.
3. Ash (%)	AACC Approved Method 08-01	Indicator of total non-specific mineral content.
4. Total starch (%)	AACC Approved Method 76-13	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 55-10	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 56-35.01	Indicator of cooking and canning behavior.
10. Unhydrated seed (%)	AACC Approved Method 56-35.01	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 different heating profile and longer run time.	Indicator of texture, firmness, and gelatinization properties of the starch.
15. Cook Firmness	AACC Approved Method 56-36.01	Indicator of pulse firmness after a cooking process. The information allows for a relative difference in texture to be established.
16. 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

Sample distribution

A total of 194 dry pea samples were collected from Idaho, Montana, North Dakota, Oregon, South Dakota and Washington from July to November 2020. Growing location, number of samples, color and cultivar/variety details of these dry pea samples were recorded (Table 3).

The majority of the pea samples were obtained from Montana and North Dakota. Green peas accounted for 77 of the samples collected, where Arcadia (17), Banner (8), Ginny (8), and Shamrock (7) accounted for the majority of the green peas evaluated. The remaining samples were a mix of various cultivars (Table 3).

Yellow peas accounted for 111 of the pea samples collected. Salamanca (20), CDC Inca (17) and AAC Profit (9) cultivars accounted for the majority of the yellow pea samples evaluated. Like green peas, the remaining samples were a mix of various cultivars (Table 3). Marrowfat (2) and Winter (4) pea were also evaluated in 2020.

Proximate composition of dry pea (Tables 4-6)

Moisture

The moisture content of dry pea ranged from 6.1-13.7% in 2020 (Table 4). The mean moisture content of all 194 pea samples was 9.5%, which is lower than the 5-year mean of 10.6%. Dry peas grown in 2020 had comparable moisture contents to pea samples from 2017 and 2018 harvest years. 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 2020, approximately 3 samples had moisture contents greater than 13%. Most pea samples had moisture contents between 8.8 and 11%

Table 3. Description of dry pea samples used in the 2020 pulse quality survey.

State	No. of Samples	Market Class	Cultivars	
Idaho	12	Green	Banner	Greenwood
			Fairway	
		Winter	Vail	
		Marrowfat	145-22	90-7
Montana	51	Green	AAC Comfort	Aragorn
			Arcadia	CDC Greenwater
			Cruiser	Daytona
			Empire	Fairway
			Ginny	Hampton
			Majoret	Shamrock
			Striker	Viper
		Yellow	AAC Carver	AAC Chrome
			AAC Profit	AC Agassiz
			AC Earlystar	Bridger
			CDC Amarillo	CDC Golden
			CDC Inca	CDC Meadow
			CDC Saffron	CDC Spectrum
			Delta	DL Apollo
			DS Admiral	Durwood
			Hyline	Jetset
			Korando	LG Amigo
			LG Sunrise	ND Dawn
			Nette 2010	Salamanca
			Yellowstone	
		Winter	Goldenwood (Yellow)	
North Dakota	118	Green	Arcadia	Banner
			Bluemoon	Cruiser
			Daytona	Empire
			Ginny	Greenwood
			Hampton	Majoret
			Shamrock	
		Yellow	AAC Carver	AAC Profit
			AC Earlystar	CDC Amarillo
			CDC Golden	CDC Inca
			Durwood	Hyline
			Korando	Majoret
			Montech	ND Dawn
			Nette 2010	Pizzaz
			Puris PP0667	Salamanca
			Spider	Treasure
Oregon	1	Green	Ariel	
South Dakota	1	Yellow	CDC Inca	
Washington	11	Green	Banner	Blaze
			Ginny	

Table 4. Proximate composition of dry pea grown in the USA, 2015-2020.

Proximate Composition (%)*	Year							
	2020		2019	2018	2017	2016	2015	5-year
	Range	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Moisture	6.1-13.7	9.5 (1.3)	12.4 (1.7)	9.6 (1.0)	9.5 (1.1)	10.1 (1.0)	10.9 (1.5)	10.6 (1.1)
Ash	1.0-3.8	2.5 (0.5)	2.4 (0.2)	2.5 (0.2)	2.5 (0.2)	2.5 (0.2)	2.5 (0.2)	2.5 (0.1)
Fat	0.6-3.9	1.7 (0.6)	2.0 (0.4)	2.8 (0.8)	2.1 (0.7)	**	**	nd
Protein	16.1-25.5	21.4 (1.5)	21.0 (1.4)	21.4 (1.6)	21.5 (1.8)	20.8 (1.6)	20.3 (1.7)	21.1 (0.7)
Total Starch	37.9-50.0	44.4 (3.1)	43.3 (1.5)	42.5 (1.9)	41.9 (2.0)	42.8 (3.1)	41.7 (4.0)	42.7 (0.6)

*composition is on an "as is" basis; **not previously reported; nd = not determined

Table 5. Proximate composition of different market classes of dry pea grown in the USA, 2015-2020.

Proximate Composition (%)*	Mean (SD) of green pea						5-year
	2020	2019	2018	2017	2016	2015	Mean (SD)
Moisture	9.2 (1.3)	11.5 (1.8)	9.2 (1.1)	9.0 (1.1)	9.6 (0.9)	10 (1)	9.9 (1.0)
Ash	2.6 (0.3)	2.4 (1.8)	2.5 (0.2)	2.5 (0.2)	2.4 (0.2)	2.5 (0.2)	2.5 (0.1)
Fat	1.6 (0.6)	2.1 (0.3)	2.9 (0.8)	2.1 (0.7)	**	**	nd
Protein	23.5 (1.3)	21.3 (0.2)	22.0 (1.8)	21.6 (2.0)	21.0 (1.8)	21 (2)	21.4 (0.4)
Total Starch	45.1 (3.0)	43.1 (1.5)	42.3 (1.6)	41.4 (2.1)	42.1 (2.9)	41 (3)	42.0 (0.8)
Proximate Composition (%)*	**Mean (SD) of yellow pea**						**5-year**
	2020	**2019**	**2018**	**2017**	**2016**	**2015**	**Mean (SD)**
Moisture	9.9 (1.1)	12.9 (1.4)	9.9 (0.9)	9.8 (0.9)	10.5 (0.9)	11.5 (1.1)	11.2 (1.2)
Ash	2.4 (0.6)	2.4 (1.2)	2.5 (0.2)	2.5 (0.2)	2.6 (0.2)	2.4 (0.2)	2.5 (0.1)
Fat	1.7 (0.6)	1.9 (0.4)	2.7 (0.8)	2.2 (0.8)	**	**	nd
Protein	21.4 (1.3)	20.8 (0.2)	21.1 (1.5)	21.4 (1.7)	20.6 (1.5)	19.9 (1.7)	21.0 (0.8)
Total Starch	43.9 (3.0)	43.4 (1.5)	42.6 (2.0)	42.2 (1.9)	43.3 (3.2)	41.2 (4.7)	42.6 (0.9)
Proximate Composition (%)*	**Mean (SD) of winter pea**						**5-year**
	2020	**2019**	**2018**	**2017**	**2016**	**2015**	**Mean (SD)**
Moisture	7.8 (0.9)	9.5 (0.2)	**	**	**	**	nd
Ash	2.5 (0.1)	2.5 (1.2)					nd
Fat	1.7 (0.4)	1.9 (0.1)	**	**	**	**	nd
Protein	21.3 (1.3)	21.3 (0)	**	**	**	**	nd
Total Starch	46.1 (2.4)	42.5 (1.2)	**	**	**	**	nd
Proximate Composition (%)*	**Mean (SD) of marrowfat pea**						**5-year**
	2020	**2019**	**2018**	**2017**	**2016**	**2015**	**Mean (SD)**
Moisture	6.8 (0.5)	14.1 (0)	**	**	**	**	nd
Ash	2.5 (0.1)	2.8 (0)					nd
Fat	2.1 (0.2)	1.8 (0)	**	**	**	**	nd
Protein	23.5 (1.3)	21.6 (0)	**	**	**	**	nd
Total Starch	43.9 (3.0)	39.4 (0)	**	**	**	**	nd

*composition is on an "as is" basis; **not previously reported; nd = not determined

Moisture (cont.)

The moisture contents of the green and yellow market classes were different by approximately 0.7 percentage points (Table 5). The green and yellow seed moisture of 9.2 and 9.9%, respectively, were approximately the same values from pea samples harvested in 2017 and 2018 but lower than the 5-year mean values (Table 5). Winter and marrowfat peas had lower moisture percentages in 2020 compared to comparable peas from 2019. The highest moisture contents were observed in the Viper (i.e., green pea) and Montech and Puris PP0667 (yellow pea) cultivars (Table 6). Most of the green peas had moisture contents in the 9 to 10% range while yellow peas had moisture contents between 9.5 and 10%.

Ash

Ash content of dry pea ranged from 1.0-3.8%, with a mean of 2.5%. The mean ash content of dry peas grown in 2020 was the same as the 5-year mean (Table 4). Only the peas from the 2019 harvest year had a lower ash content. Ash content is a general indicator of minerals present. The ash contents of yellow and green market classes were 2.6 and 2.4%, respectively (Table 5). The green and yellow pea ash contents were similar to their respective 5-year mean value of 2.5%. Some variability in ash content was observed among cultivars (Table 6). The ash percentage in individual samples ranged from 1.0% in AAC profit to 3.8% in Nette 2010. However, in cultivars where multiple samples were analyzed, the ash percentage ranged from 1.8% in the Durwood cultivar to 3.1% (Daytona).

Fat (Lipid)

Fat content of dry pea ranged from 0.6 to 3.9%, with a mean of 1.7%. The 2020 evaluation represents the fourth year of the fat analysis for the pea samples. Thus, no long-term data is available for comparison. However, the mean fat content of pea harvested in 2020 was lower than fat content of pea harvested in previous years. The fat contents of the green and yellow market classes were approximately the same (Table 5). Only marrowfat pea had a mean fat content greater than 2%. CDC Greenwater (green) and Delta (yellow) had the highest fat contents in their respective market classes (Table 6). In contrast, AAC Comfort (green) and Pizzaz and AAC Chrome (yellow) had the lowest fat contents among their respective market classes. AAC Comfort also had the lowest fat content of the pea samples grown in 2019.

Protein

Protein content of dry pea harvested in 2020 ranged from 16.1 to 25.5% with a mean of 21.4% (Table 4). The mean protein content was comparable to the peas from the 2017 and 2018 harvest years and higher than protein from the 205, 2016 and 2019 harvest years by not less than 0.5 percentage points. The mean protein content of dry peas grown in 2020 was slightly higher than the 5-year mean of 21.1%. The mean protein content of the green and marrowfat pea samples were 2.1 percentage points higher than the mean protein content of the yellow and winter pea samples. Similar trends in protein data between market classes were observed in prior harvest years (Table 5). Green pea samples had a mean protein content of 23.5% while the 5-year mean value was 21.1%. Yellow peas had a mean protein content (21.4%), which was slightly higher than the 5-year mean protein value (21.0%). Ariel and Fairway (green, 23.9 and 23.8%, respectively) and Pizzaz (yellow, 22.8%) cultivars had the highest protein contents in their respective market classes (Table 6). In contrast, Arcadia (green) and Bridger (yellow) had the lowest protein percentages among their respective market classes. Both marrowfat pea varieties had protein contents of 23.5%.

Total starch

Total starch content of dry pea ranged from 37.9 to 50.0% with a mean of 44.4%. The mean total starch content of dry peas grown in 2020 was comparable to mean total starch in dry peas from the 2019 harvest year (i.e., 43.3%) and was higher than the 5-year mean of 42.7%. The starch contents of the green and yellow market classes were 45.1 and 43.9%, respectively (Table 5). Green peas had a mean starch content that was higher than the 5-year mean value of 42.0%. Furthermore, the starch content of peas from 2020 was significantly higher than in peas from other harvest years. The 5-year mean starch value for the yellow peas also was lower (42.6%) than the mean starch content (43.9%) of yellow peas harvested in 2020. Unlike green peas, the peas from the 2020 most closely matched the peas harvested in 2016 and 2019. Winter peas had the highest mean starch percentage at 46.1%. Cruiser and Majoret had the highest (448.6 and 48.5%, respectively) starch content among the green peas while LG Sunrise had the highest starch content (49.2%) among yellow pea samples. Bluemoon (41.0%) and DL Apollo (40.1%) had the lowest starch contents in green and yellow peas, respectively (Table 6).

In 2020, winter and marrowfat pea samples had higher starch percentages that peas grown in 2019 (Table 5). The total starch tended to be higher in both the winter and marrowfat samples in 2020. Differences among cultivars also was observed (Table 6). The general trend for all samples supports a higher protein and starch contents and lower fat contents in samples grown in 2020 compared to previous years.

Table 6. Mean proximate composition of dry pea cultivars grown in the USA in 2020.

		Concentration (%)				
Market Class	Cultivar	Moisture	Ash	Fat	Protein	Starch
Green	AAC Comfort*	9.2	2.7	0.8	21.6	47.5
	Aragorn	8.9	2.2	1.3	20.7	42.6
	Arcadia	10.0	2.6	1.3	19.9	45.7
	Ariel*	6.5	2.5	1.5	23.9	43.8
	Banner	7.8	2.5	2.0	21.6	42.6
	Bluemoon	10.8	3.0	1.1	20.2	41.0
	CDC Greenwater*	8.9	2.4	3.1	20.8	41.7
	Cruiser	10.1	2.6	1.7	20.9	48.6
	Daytona	9.7	3.1	1.2	21.5	43.5
	Empire	9.3	2.7	1.5	21.8	45.9
	Fairway	7.7	2.7	1.6	23.8	46.7
	Ginny	8.3	2.3	1.8	22.3	45.4
	Greenwood	9.1	2.6	2.7	20.9	44.1
	Hampton	9.4	2.7	1.6	20.9	44.0
	Majoret	9.5	2.7	1.2	22.8	48.5
	Shamrock	8.8	2.8	1.6	22.2	46.2
	Striker*	8.7	2.7	1.3	22.1	42.6
	Viper	11.9	2.3	1.3	20.3	46.1
Yellow	AAC Carver	10.5	3.0	1.6	21.3	42.0
	AAC Chrome*	8.9	3.2	1.0	20.5	45.9
	AAC Profit	10.5	2.3	1.6	20.4	43.3
	AC Agassiz*	8.9	3.0	1.1	20.7	46.9
	AC Earlystar	9.7	2.0	1.9	19.1	45.8
	Blaze	7.9	2.3	1.8	22.3	42.7
	Bridger*	10.2	3.1	2.3	18.3	43.1
	CDC Amarillo	9.8	2.3	2.1	22.0	46.5
	CDC Golden	10.0	2.3	1.2	21.1	45.1
	CDC Inca	10.1	2.2	1.8	21.4	44.8
	CDC Meadow*	10.1	3.3	1.8	20.9	41.5
	CDC Saffron*	9.2	2.1	1.9	20.7	43.6
	CDC Spectrum*	8.8	3.0	2.0	21.2	45.2
	Delta*	8.6	2.8	3.0	21.6	46.4
	DL Apollo*	9.1	2.7	1.9	21.0	40.1
	DS Admiral*	9.3	3.0	1.5	21.2	47.2
	Durwood	10.1	1.8	1.4	21.7	43.6
	Hyline	9.6	2.4	1.8	20.2	43.1
	Jetset*	8.5	3.4	1.7	21.3	42.9
	Korando	9.9	2.1	1.7	21.6	42.9
	LG Amigo*	8.9	3.5	2.4	21.1	42.0
	LG Sunrise*	8.8	2.7	2.1	19.5	49.2
	Montech*	11.1	2.5	2.4	21.9	42.7
	ND Dawn	9.1	2.7	1.7	21.7	44.2
	Nette 2010	9.0	2.7	1.8	22.1	44.7
	Pizzaz*	10.3	3.2	0.7	22.8	44.0
	Puris PP0667	11.1	2.1	1.7	21.1	40.9
	Salamanca	10.4	2.2	1.8	22.3	43.6
	Spider*	9.9	2.2	1.6	21.8	45.7
	Treasure	10.6	1.8	1.5	20.7	45.2
	Yellowstone*	9.1	2.6	1.7	20.1	41.3
Winter	Goldenwood*	9.0	2.5	1.3	21.4	49.6
	Vail	7.4	2.5	1.9	21.3	44.9
Marrowfat	145-22*	6.4	2.6	2.3	23.5	41.7
	90-7*	7.1	2.4	2.0	23.5	37.9

*Only one sample of cultivar tested

Physical parameters of dry pea (Tables 7-11)

Test weight ranged from 46.3 to 67 lbs/bu with a mean of 63.6 lbs/bu. This mean value was the approximately 0.4 lbs/bu lower than the 5-year mean of 64 lbs/bu (Table 7). The mean test weight for all pea samples harvested in 2020 was comparable to those from 2016-2018. The test weights of peas in the green and yellow market classes were 64 and 63 lbs/bu, respectively (Table 8). These values were approximately 1 lbs/bu higher and lower than the 5-year mean values, respectively. Winter pea had the highest test weight at 65 lbs/bu. The test weight of individual cultivars was comparable to one another within green and yellow market classes with few exceptions (Table 9). Viper (green) and Treasure (yellow) had the highest test weights in their respective market classes. The lowest test weights were 63.1 and 62.0 lbs/bu for the Fairway (green) and Bridger (yellow) cultivars, respectively (Table 9).

The range and mean **1000 seed weight** of dry peas grown in 2020 were 145-318 g and 233 g, respectively (Table 7). The mean value (233g) was higher than the mean 1000 seed weight of peas evaluated in the 2015 to 2019. This supports heavier seeds for the peas harvested in 2020. Peas of the green market class had a mean 1000 seed weight of 220 g, which is significantly higher than the 5-year mean value of 202 g (Table 8). Peas of the yellow market class had a mean 1000 seed weight of 244 g, which is the 20 grams higher than the 5-year mean 1000 seed weight (Table 8). The 1000 seed weight for pea from 2020 were significantly higher than seed weight from peas obtained in 2015-2019 harvest years. Winter pea samples harvested in 2020 also had higher 1000 seed weight compared to peas harvested in 2019. In contrast, 1000 seed weight of the 2020 marrowfat peas samples was lower than the value obtained in 2019.

The individual cultivars (Table 9) varied extensively in 1000 seed weight, where the cultivars in the green market class varied (177 to 274 g) less than cultivars in the yellow market class (182 to 293 g). Ariel (177 g) and Blaze (182 g) and Daytona (274 g) and Yellowstone (293 g) had the lowest and highest 1000 seed weight in the green and yellow market class, respectively (Table 9). The overall lowest 1000 seed weight was observed in the winter pea where a difference of 11 g was observed between Vail and Goldenwood. Marrowfat varieties test were also different by 36 g. The test weight and 1000 seed weight support that the peas from 2020 were larger than the peas from previous crop years with only a few exceptions.

Table 7. Physical parameters of dry pea grown in the USA, 2015-2020.

Physical Parameter	Year 2020 Range	2020 Mean (SD)	2019	2018	2017	2016	2015	5-year Mean (SD)
Test Weight (lbs/bu)	46.3-67.0	63.6 (1.9)	64.3 (1)	63.5 (1)	63 (2)	63 (4)	64 (2)	64 (1)
1000 Seed Wt. (g)	145-318	233 (33.0)	224 (31)	211 (33)	204 (32)	224 (29)	215 (36)	216 (9)
Water Hydration Capacity (%)	68-119	97 (8.0)	96 (8)	103 (8)	104 (14)	97 (6)	102 (16)	102 (6)
Unhydrated Seeds (%)	0-17	2 (3)	2 (3)	1 (2)	2 (2)	2 (3)	2 (2)	2 (0)
Swelling Capacity (%)	89-159	118 (12.4)	145 (13)	147 (14)	148 (10)	137 (16)	152 (17)	146 (6)
Cooked Firmness (N/g)	11.5-48.3	24.9 (6.3)	21.0 (7)	21.0 (5)	24 (6)	23 (5)	21 (6)	22 (1)

Table 8. Physical parameters of different market classes of dry pea grown in the USA, 2015-2020.

Physical Parameter	Mean (SD) of green pea 2020	2019	2018	2017	2016	2015	5-year Mean (SD)
Test Weight (lbs/bu)	64 (2)	64 (1)	63 (1)	63 (2)	63 (6)	63 (2)	63 (0)
1000 Seed Wt. (g)	220 (31)	207 (28)	192 (28)	190 (28)	213 (29)	207 (43)	202(10)
Water Hydration Capacity (%)	99 (7)	99 (6)	106 (8)	107 (20)	100 (6)	114 (11)	105 (6)
Unhydrated Seeds (%)	2 (2)	1 (1)	0 (1)	2 (2)	1 (1)	2 (2)	1 (1)
Swelling Capacity (%)	120 (12)	144 (10)	149 (12)	146 (11)	140 (16)	142 (23)	144 (3)
Cooked Firmness (N/g)	21.7 (4)	18.9 (4.6)	19.8 (5)	22 (5)	23 (5)	17 (5)	20 (2)
Physical Parameter	**Mean (SD) of yellow pea 2020**	**2019**	**2018**	**2017**	**2016**	**2015**	**5-year Mean (SD)**
Test Weight (lbs./bu)	63 (2)	64 (1)	63 (1)	63 (2)	64 (1)	62 (2)	64 (1)
1000 Seed Wt. (g)	244 (28)	222 (31)	214 (30)	231 (27)	220 (32)	211 (38)	224 (8)
Water Hydration Capacity (%)	93 (7)	102 (8)	102 (5)	95 (6)	110 (18)	99 (13)	101 (6)
Unhydrated Seeds (%)	2 (3)	0 (2)	1 (1)	2 (4)	2 (2)	2.0 (2)	1 (1)
Swelling Capacity (%)	116 (12)	146 (14)	150 (9)	135 (16)	147 (14)	149 (13)	145 (6)
Cooked Firmness (N/g)	27.2 (6.6)	22.0 (7.1)	21.7 (5)	25 (6)	22 (5)	22 (6)	23 (1)
Physical Parameter	**Mean (SD) of winter pea 2020**	**2019**	**2018**	**2017**	**2016**	**2015**	**5-year Mean (SD)**
Test Weight (lbs/bu)	65 (0.4)	65 (0)	**	**	**	**	nd
1000 Seed Wt. (g)	175 (12)	154 (39)					nd
Water Hydration Capacity (%)	96 (5)	85 (8)	**	**	**	**	nd
Unhydrated Seeds (%)	1 (1)	7 (8)	**	**	**	**	nd
Swelling Capacity (%)	119 (8)	131 (3)					
Cooked Firmness (N/g)	21.6 (1.6)	24.6 (8.3)	**	**	**	**	nd
Physical Parameter	**Mean (SD) of marrowfat pea 2020**	**2019**	**2018**	**2017**	**2016**	**2015**	**5-year Mean (SD)**
Test Weight (lbs/bu)	62 (1)	63 (0)	**	**	**	**	nd
1000 Seed Wt. (g)	300 (26)	333 (0)					nd
Water Hydration Capacity (%)	111 (6)	110 (0)	**	**	**	**	nd
Unhydrated Seeds (%)	0 (0)	1 (0)	**	**	**	**	nd
Swelling Capacity (%)	136 (3)	169 (0)					
Cooked Firmness (N/g)	23.6 (5.1)	16.1 (0)	**	**	**	**	nd

**not previously reported; nd = not determined

Water hydration capacity of dry peas ranged from 68 to 119%, with a mean of 97% (Table 7). The 2020 mean value is comparable to the water hydration capacity of peas from 2016 and 2019. Peas from other individual harvest years had slightly higher water hydration capacity compared to 2020. The mean water hydration capacity of peas in the green market class was six and three percentage points higher than the mean hydration capacity of the yellow and winter market classes (Table 8). However, the mean water hydration capacity of the green peas was 12 percentage point lower than that of marrowfat peas. The water hydration capacities in the peas from 2020 were comparable to peas from 2016 and 2019 but lower than the 5-year mean water hydration capacity of the green market class. The yellow peas from 2020 had water hydration capacities most similar to the peas from the 2017 harvest year. In the green market class, Striker and Shamrock had the lowest (87%) and highest (107%) water hydration capacities, respectively. The water hydration capacity ranged from 84% in Yellowstone to 110% in Pizzaz cultivars (Table 9). Marrowfat pea had the highest water hydration capacity (115%) of the pea samples.

Table 9. Mean physical parameters of USA dry pea cultivars grown in 2020.

Market Class	Cultivar	Test Weight (lbs/bu)	1000 Seed Weight (g)	Water Hydration Capacity (%)	Unhydrated Seeds (%)	Swelling Capacity (%)	Cooked Firmness (N/g)
Green	AAC Comfort*	64.1	269	90	3	102	22.6
	Aragorn	64.3	223	99	0	114	24.3
	Arcadia	63.7	217	99	1	122	24.0
	Ariel*	63.9	177	102	0	124	21.0
	Banner	64.6	191	103	2	126	18.9
	Bluemoon	64.4	223	97	6	115	20.0
	CDC Greenwater*	65.1	239	98	1	106	25.1
	Cruiser	64.1	216	96	2	119	22.7
	Daytona	64.2	274	91	1	114	21.7
	Empire	65.7	244	98	3	117	15.7
	Fairway	63.1	181	104	0	124	21.5
	Ginny	64.4	196	103	1	125	20.8
	Greenwood	65.0	221	95	3	115	24.2
	Hampton	64.0	224	95	4	120	25.5
	Majoret	64.1	237	89	3	98	22.0
	Shamrock	64.5	228	107	1	132	19.3
	Striker*	65.0	257	87	8	97	22.8
	Viper	65.9	232	95	0	120	23.2
Yellow	AAC Carver	62.8	237	93	0	110	27.3
	AAC Chrome*	63.2	255	91	2	106	26.2
	AAC Profit	63.0	248	91	2	115	25.6
	AC Agassiz*	62.5	237	98	1	112	27.4
	AC Earlystar	64.3	212	97	1	121	23.0
	Blaze	64.4	182	109	1	143	18.5
	Bridger*	62.0	253	100	1	133	13.4
	CDC Amarillo	63.1	254	92	1	116	33.7
	CDC Golden	63.6	225	93	3	113	18.5
	CDC Inca	62.8	235	91	1	112	30.9
	CDC Meadow*	63.8	211	90	9	117	23.7
	CDC Saffron*	63.3	262	89	1	111	27.2
	CDC Spectrum*	62.4	252	91	2	107	26.4
	Delta*	64.5	249	92	3	118	19.5
	DL Apollo*	63.7	235	93	2	107	26.2
	DS Admiral*	64.0	250	93	4	104	33.4
	Durwood	63.4	264	89	0	108	31.1
	Hyline	63.9	244	94	0	115	27.8
	Jetset*	63.2	250	96	1	115	37.9
	Korando	62.8	273	93	1	113	32.2
	LG Amigo*	62.7	243	96	0	110	28.3
	LG Sunrise*	64.0	246	87	4	94	33.4
	Montech*	61.6	268	95	0	126	24.8
	ND Dawn	62.2	252	96	3	128	25.4
	Nette 2010	62.8	251	94	4	108	32.6
	Pizzaz*	63.8	222	110	1	159	15.7
	Puris PP0667	62.2	238	77	11	101	25.2
	Salamanca	62.4	260	94	1	118	26.8
	Spider	63.5	230	96	1	115	23.0
	Treasure	65.2	231	87	5	114	26.6
	Yellowstone*	63.7	293	84	10	96	27.5
Winter	Goldenwood*	64.1	183	101	2	126	22.8
	Vail	64.6	172	95	0	117	21.1
Marrowfat	145-22*	61.8	318	115	0	138	27.3
	90-7*	62.9	282	107	0	134	20.0

*Only one sample of cultivar tested

Unhydrated seed percentage ranged from 0-17% with a mean of 2%, which equals the 5-year mean unhydrated seed percentage (Table 7). Green and yellow peas had unhydrated seed values of 2% (Table 8). These values were higher than those from the winter and marrowfat classes. However, the green and yellow pea samples had comparable unhydrated seed percentages as the 5-year mean value (Table 8). Several of the green pea cultivars had unhydrated seed rates of 0 while Striker had unhydrated seed rate of 8% (Table 9). Like green peas, several yellow cultivars had 0 unhydrated seed numbers. However, Puris PPO667 had the highest unhydrated seed number at 11%. 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 rehydration of the dry pea. The swelling capacity of all peas ranged from 89% to 159% with a mean value of 118% (Table 7). The mean swelling capacity for peas from the 2020 harvest was significantly lower than values obtained in previous harvest years and was less than the 5-year mean value. The swelling capacity of green peas was about 4 percentage point higher than the yellow pea (Table 8), but less than the 136% observed for the Marrowfat pea. Variability in the swelling capacity among cultivars was observed (Table 9). Striker (green) and LG Sunrise (yellow) had the least swelling capacity while Shamrock (green) and Pizzaz (yellow) had the highest swelling capacities among the cultivars tested (Table 9).

The **cooked firmness** values were slightly higher in the peas from 2020 compared to those of 2015-2019. The cooked firmness for all peas ranged from 11.5 to 48.3 N/g with a mean value of 24.9 N/g (Table 7). The cooked firmness of peas was different between market classes (Table 8). The green peas had lower firmness values than those of the yellow peas. The value obtained in 2020 was comparable to the mean firmness value obtained from cooked green pea in 2017. The cooked firmness values in yellow peas from 2020 were significantly higher than firmness values in yellow peas from previous harvest years except 2017. Among the green cultivars, Empire had the lowest cooking firmness (15.7 N/g) while Hampton (25.5 N/g) was the firmest (Table 9). In 2019, Empire and Hampton also had the lowest and highest cooked firmness of the green pea cultivars, respectively. Jetset had the highest (37.9 N/g) cooking firmness among the yellow cultivars tested while Bridger (13.4 N/g) had the lowest cooked firmness (Table 9). The winter and marrowfat peas had cooked firmness values that were in the low to mid 20 N/g range.

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 2020 indicated that the peas had L* values that were higher than the L* values of the peas from previous years except 2015 (Table 10). This observation was true for both green, yellow and marrowfat peas. However, the winter pea had mean L* values lower than the previous year. The 2020 winter pea were primarily of green color and thus that likely contributed to the lower L* for the 2020 samples. Overall, the higher L* indicates that the peas from the 2020 crop year were lighter in color than those from previous years except 2015. The negative value for red-green (i.e., a* value) value in 2020 less green color compared to samples from 2015, 2018 and 2019 but similar greenness to green peas from 2017 (Table 10). The b* value for green peas was comparable to the green peas from 2019 but was significantly lower than b* value of green peas from other harvest years. The lower b* value indicates a bluer color compared to the peas from 2015 to 2018 crop years. The higher b* values combined with the a* value on the green part of the scale (i.e., negative number) indicates that the samples would be a light green 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 2020 appear greener in color compared to those from previous years except 2019. For the yellow pea market class, the 2020 crop had lightness values higher than previous pea samples except for the pea samples from 2015. The pea samples were slightly lighter than the peas from the 2016 to 2019 crop years. 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 2020 had a* values that were similar to a* values in peas from 2019. The b* values for yellow peas from 2020 were most similar to b* values of peas from 2019 crop year. However, the yellowness of peas from 2020 was less than that of peas from 2015 to 2018. A higher b* values combined with the 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 color. Therefore, the yellow peas in 2020 appeared dark yellow compared to peas from 2015-2018. However, the peas from 2020 would be similar in appearance to the peas from 2019 (Table 10). For winter pea, the 2020 pea samples were darker, greener and bluer than the samples from 2019. As indicated above, more green winter pea samples were provided and thus supporting the observed color. Marrowfat peas from 2020 tended to be lighter green in color compared to the samples from 2019.

The color of the dry peas changed after the soaking process. The change in color was less for green peas from the 2020 crop year compared to the previous crop years except 2019 (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 opposite of the 2019 crop year but similar to previous crop years. In 2020, lightness increased after soaking of the yellow peas, but to a lesser extent compared to the samples from 2019. Although, the L* change was similar to that observed in the 2017 and 2018 pea samples. In addition, soaking caused a reduction in greenness (i.e., higher a* value) and increased yellowness (i.e., higher b* value) of the yellow peas. This suggests that the peas appeared more yellow after soaking (Table 10). 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. The color difference values observed in 2020 were less than in samples from previous years except 2019. Greater color differences were observed in yellow pea samples from 2016 – 2018 compared to 2020, while smaller color differences in yellow peas from 2015 and 2019.

The Daytona and Shamrock cultivars from 2020 had the lowest L* values (Table 11). Shamrock had the most negative a* value and one of the lowest b* values, giving it a dark green appearance. AAC Comfort had the highest L*, a* and b* values, giving it a light green appearance. Unlike 2019, 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). The greatest color difference was observed in the AAC Comfort cultivar while Shamrock underwent the least color change.

Table 10. Color quality of dry pea grown in the USA before and after soaking in water 16 hours, 2015-2020.

Color Scale[#]	Mean (SD) of green pea											
	Before Soaking						After Soaking					
	2020	2019	2018	2017	2016	2015	2020	2019	2018	2017	2016	2015
L* (lightness)	58.82 (2.75)	48.99 (3.35)	51.68 (3.57)	52.69 (2.82)	52.01 (2.47)	62.32 (4.11)	54.69 (3.26)	50.42 (4.09)	45.49 (2.42)	47.52 (3.22)	46.86 (2.68)	57.83 (4.27)
a* (red-green)	-1.35 (1.97)	-2.46 (0.92)	-1.92 (0.77)	-1.24 (1.15)	-0.98 0.86	-3.53 (1.48)	-6.47 (3.45)	-6.28 (1.20)	-6.16 (0.77)	-5.24 (1.91)	-5.14 (1.18)	-9.07 (3.87)
b* (yellow-blue)	9.84 (1.51)	9.23 (0.92)	14.15 (1.49)	15.11 (1.51)	14.01 (1.26)	15.31 (1.52)	17.50 (3.24)	12.63 (2.25)	28.52 (2.65)	28.63 (2.74)	27.39 (1.82)	22.57 (6.28)
Color Difference	10.78 (1.93)	6.44 (3.05)	16.45 (2.53)	15.39 (2.64)	15.17 (2.02)	11.44 (5.34)						
Color Scale	**Mean (SD) of yellow pea**											
	Before Soaking						After Soaking					
	2020	2019	2018	2017	2016	2015	2020	2019	2018	2017	2016	2015
L* (lightness)	63.42 (2.64)	56.69 (2.98)	58.76 (2.39)	58.73 (1.70)	57.29 (2.52)	71.33 (1.87)	65.03 (1.47)	60.74 (2.03)	59.96 (1.98)	60.56 (2.19)	69.51 (1.71)	68.00 (3.78)
a* (red-green)	4.99 (0.68)	4.97 (0.71)	6.91 (0.99)	6.83 (1.34)	7.16 (0.84)	6.51 (0.79)	5.50 (0.75)	3.89 (1.20)	9.38 (0.98)	9.60 (2.38)	9.62 (0.90)	4.65 (1.73)
b* (yellow-blue)	14.61 (0.95)	14.48 (1.75)	19.21 (1.53)	20.40 (1.92)	19.35 (1.37)	21.99 (2.23)	28.89 (1.41)	21.15 (3.19)	37.67 (2.65)	38.25 (4.44)	36.70 (2.55)	27.56 (5.19)
Color Difference	14.63 (2.06)	8.46 (2.52)	19.10 (2.95)	18.67 (3.64)	19.96 (2.52)	8.41 (5.24)						
Color Scale	**Mean (SD) of winter pea**											
	Before Soaking						After Soaking					
	2020	2019	2018	2017	2016	2015	2020	2019	2018	2017	2016	2015
L* (lightness)	56.09 (2.03)	58.76 (2.39)	**	**	**	**	53.77 (5.52)	59.96 (1.98)	**	**	**	**
a* (red-green)	-0.84 (1.99)	6.91 (0.99)	**	**	**	**	-5.27 (5.44)	9.38 (0.98)	**	**	**	**
b* (yellow-blue)	10.34 (2.88)	19.21 (1.53)	**	**	**	**	20.33 (7.47)	37.67 (2.65)	**	**	**	**
Color Difference	12.38 (3.49)	19.10 (2.95)	**	**	**	**						
Color Scale	**Mean (SD) of marrowfat pea**											
	Before Soaking						After Soaking					
	2020	2019	2018	2017	2016	2015	2020	2019	2018	2017	2016	2015
L* (lightness)	60.06 (1.30)	56.69 (2.98)	**	**	**	**	57.55 (0.05)	60.74 (2.03)	**	**	**	**
a* (red-green)	-0.59 (0.21)	4.97 (0.71)	**	**	**	**	-7.70 (4.03)	3.89 (1.20)	**	**	**	**
b* (yellow-blue)	10.90 (0.04)	14.48 (1.75)	**	**	**	**	20.54 (3.65)	21.15 (3.19)	**	**	**	**
Color Difference	12.32 (5.52)	8.46 (2.52)	**	**	**	**						

[#]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. **Not determine.

The cultivars of the yellow peas had L* values between 61.37 and 66.85, with ND Dawn being the darkest and AC Earlystar being the lightest (Table 11). Blaze retained the darkest color after soaking while AC Agassiz became the lightest. LG Amigo had the highest redness (a* value) while the lowest was observed for the Blaze (Table 11). After soaking, LG Amigo again had the highest redness value while Blaze also had the lowest redness. The yellowness of the dry yellow pea was greatest for Montech and lowest for Salamanca cultivars. After soaking, LG Sunrise had the highest yellowness values while Montech had the lowest. The greatest color difference was observed in the Jetset cultivar. The increase in lightness and yellowness during soaking likely contributed to the greatest color difference. Montech had the least color change during soaking.

As expected, Vail winter pea was darker, greener and less yellow than the Goldenwood since Vail is a green winter while Goldenwood was yellow. The difference in color was more pronounced after soaking where Goldenwood had a higher color difference score (Table 11). Marrowfat pea samples had similar presoaked color values while after soaking 90-7 was greener and more yellow. The significant changes in the a* and b* values likely contributed to the higher color difference scores of the 90-7 marrowfat pea.

Pasting Properties (Tables 12-14)

The peas from 2020 had peak, and hot paste viscosities values that were most similar to peas from 2017 and 2018 and were slightly lower than the 5-year mean (Table 12). However, cold paste viscosity of the pea samples from 2020 were similar to the cold past viscosity for peas harvested in previous years except 2016. Mean peak time was slightly longer than the 5-year mean value. Pasting temperature ranged from 68.5 to 83.3 °C, with a mean of 77.7°C. The mean value is comparable to peas from 2015 and 2018 years and slightly higher than the 5-year mean pasting temperature. The pasting characteristics were similar between the green, yellow and winter pea market classes. Marrowfat pea samples tended to have lower viscosity properties than the other market classes. Pea flour peak viscosities of 138 and 132 RVU were recorded for the green and yellow market classes, respectively (Table 13). Green peas from 2020 had peak viscosities similar to peas harvested in 2017 and 2018 and the 5-year mean. Hot paste viscosity of green peas from 2020 were less than values in peas from 2016, but comparable to peas harvested in 2017-2019. The mean cold paste viscosity of green pea from 2020 was higher than other harvest years except 2016. The cold paste viscosity suggests that the gel formed during pasting would be firmer for the samples from 2020 compared to previous years.

Table 11. Color quality of USA dry pea cultivars before and after soaking, 2020.

Market Class	Cultivar	Mean Color Values[#] Before Soaking L*	a*	b*	After Soaking L*	a*	b*	Color Difference
Green	AAC Comfort**	63.02	1.91	11.84	60.92	-1.13	23.58	13.61
	Aragorn	59.64	-2.35	8.92	53.06	-7.77	15.56	10.85
	Arcadia	60.96	-0.19	11.04	56.86	-4.57	19.51	11.50
	Ariel**	59.73	-2.33	9.15	51.71	-10.93	18.44	14.99
	Banner	56.94	-1.84	9.43	53.00	-7.19	16.90	10.14
	Bluemoon	57.77	-1.89	9.29	52.62	-7.24	15.10	9.45
	CDC Greenwater**	60.61	-1.92	8.24	52.81	-8.61	16.91	12.63
	Cruiser	60.78	0.46	10.58	56.95	-3.14	20.10	12.29
	Daytona	54.25	-0.99	9.33	56.64	-6.46	17.45	12.79
	Empire	60.33	-0.97	8.38	56.08	-5.89	17.34	11.15
	Fairway	56.99	-2.51	9.82	51.18	-7.72	14.91	9.35
	Ginny	59.18	-2.06	9.42	53.43	-7.98	16.42	10.89
	Greenwood	56.16	-2.12	8.91	53.64	-7.55	17.22	10.28
	Hampton	59.13	-1.98	10.36	53.96	-7.28	16.30	9.57
	Majoret	58.99	-0.55	9.84	56.59	-6.72	17.87	10.62
	Shamrock	54.76	-2.93	9.76	51.85	-7.34	16.06	8.41
	Striker**	60.79	-1.68	8.12	56.44	-7.79	16.82	11.50
	Viper	61.98	-1.48	9.29	55.02	-7.48	17.47	12.32
Yellow	AAC Carver	63.63	5.39	14.20	66.14	5.86	30.35	16.42
	AAC Chrome**	65.03	4.87	14.23	65.75	5.36	30.60	16.39
	AAC Profit	63.84	5.25	14.72	65.70	5.33	29.16	14.62
	AC Agassiz**	66.76	5.04	14.47	68.32	4.55	28.63	14.26
	AC Earlystar	66.85	5.03	15.46	66.08	4.93	29.67	14.27
	Blaze	60.65	2.63	14.30	60.75	3.33	29.74	15.49
	Bridger**	65.12	5.19	15.62	65.46	5.93	27.10	11.50
	CDC Amarillo	63.43	5.37	14.86	65.87	5.61	29.06	14.44
	CDC Golden	63.65	4.76	14.78	64.62	5.34	30.37	15.65
	CDC Inca	61.82	5.10	14.57	64.74	5.82	28.84	15.15
	CDC Meadow**	64.16	5.17	15.95	64.23	6.32	31.17	15.28
	CDC Saffron**	65.74	4.95	14.03	66.66	4.96	27.65	13.67
	CDC Spectrum**	64.10	5.33	14.42	66.46	5.47	30.14	15.92
	Delta**	65.17	5.42	14.81	66.83	5.24	29.91	15.19
	DL Apollo**	64.89	5.34	15.97	66.32	5.33	31.01	15.11
	DS Admiral**	65.29	5.23	15.80	66.25	4.95	29.81	14.06
	Durwood	64.41	4.74	14.25	65.33	5.45	28.78	14.63
	Hyline	64.92	4.83	15.27	65.41	5.41	29.94	14.74
	Jetset**	64.58	5.35	14.29	66.82	4.90	31.15	17.08
	Korando	64.69	4.91	14.32	64.65	5.44	27.52	13.30
	LG Amigo**	65.12	5.91	14.23	66.08	6.88	29.80	15.63
	LG Sunrise**	64.33	4.98	15.00	65.25	5.68	31.39	16.43
	Montech**	62.59	5.62	16.22	65.44	6.47	27.04	11.22
	ND Dawn	61.37	5.35	14.64	64.79	5.74	28.99	15.83
	Nette 2010	62.08	4.66	14.60	65.95	4.84	29.28	15.24
	Pizzaz**	63.61	4.71	15.36	64.08	6.57	29.30	14.07
	Puris PP0667	62.91	5.56	16.03	63.76	5.82	28.41	12.45
	Salamanca	64.13	4.97	13.98	65.12	5.76	27.50	13.65
	Spider**	63.26	4.99	15.20	65.41	6.29	29.94	14.97
	Treasure	64.22	5.32	15.49	64.37	5.29	28.71	13.24
	Yellowstone**	65.78	5.42	14.48	65.53	6.37	29.50	15.05
Winter	Goldenwood**	58.78	2.03	14.57	61.98	2.81	31.26	17.02
	Vail	55.20	-1.79	8.93	51.03	-7.97	16.69	10.83
Marrowfat	145-22**	59.14	-0.74	10.87	57.52	-4.86	17.96	8.41
	90-7**	60.98	-0.45	10.93	57.59	-10.55	23.12	16.22

[#]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 pasting characteristics of the yellow pea samples were most comparable to peas from 2015 (Table 13). However, the viscosity values for peas from 2020 were lower than other harvest years. Furthermore, the viscosity values from the yellow pea samples were lower than the 5-year mean viscosity values. Within each market class, variability in starch characteristics was observed among cultivars. In the green pea, the Viper cultivar had the highest peak, hot paste, and cold paste viscosities (Table 14). In contrast, the Banner cultivar had the lowest peak, hot paste and cold paste viscosities. Puris PP0667 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 Blaze cultivar (Table 14). The Goldenwood winter pea had higher peak, hot paste, and cold paste viscosities compared to the Vail cultivar. The marrowfat peas tended to have low viscosity values compared to other peas. The 145-22 line had higher peak, hot paste, and cold paste viscosities compared to the line 90-7. 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 24 RVU, which represents little breakdown of the starch paste.

Table 12. Starch characteristics of dry peas grown in the USA, 2015-2020.

Starch Characteristic	2020 Range	2020 Mean (SD)	2019 Mean (SD)	2018 Mean (SD)	2017 Mean (SD)	2016 Mean (SD)	2015 Mean (SD)	5-Year Mean (SD)
Peak Viscosity (RVU)	89-181	134 (5)	146 (15)	139 (15)	139 (12)	146 (25)	136	142 (4)
Hot Paste Viscosity (RVU)	86-157	124 (14)	131 (12)	129 (13)	129 (10)	132 (18)	127	130 (1)
Breakdown (RVU)	1-30	10 (5)	16 (6)	10 (5)	10 (5)	14 (10)	8	12 (3)
Cold Paste Viscosity (RVU)	140-322	229 (38)	233 (30)	235 (33)	232 (31)	251 (58)	229	237 (8)
Setback (RVU)	47-178	105 (26)	104 (22)	105 (22)	103 (23)	119 (4)	102	107 (7)
Peak Time (Minute)	4.80-7.00	5.29 (0.41)	5.11 (0.40)	5 (0)	5 (1)	5 (1)	5	5.14 (0.15)
Pasting Temperature (°C)	68.5-83.3	77.7 (1.8)	76.4 (1.3)	77.6 (2.1)	76 (3)	76 (3)	77	76.7 (0.8)

Table 13. Starch characteristic of different market classes of dry peas grown in the USA, 2015-2020.

Starch	Mean (SD) of green pea						5-year
Characteristics	2020	2019	2018	2017	2016	2015	Mean (SD)
Peak Viscosity (RVU)	138 (16)	143 (17)	139 (15)	137 (12)	147 (23)	129 (19)	139 (7)
Hot Paste Viscosity (RVU)	127 (13)	127 (14)	128 (13)	127 (10)	131 (18)	122 (17)	127 (3)
Breakdown (RVU)	11 (3)	16 (6)	11 (5)	10 (5)	15 (9)	6 (5)	12 (4)
Cold Paste Viscosity (RVU)	239 (40)	220 (32)	228 (38)	231 (34)	253 (58)	219 (41)	230 (14)
Setback (RVU)	112 (29)	93 (22)	101 (27)	104 (25)	122 (43)	97 (25)	103 (11)
Peak Time (Minute)	5.29 (0.30)	5.17 (0.35)	5 (1)	5 (1)	5 (1)	6 (1)	5.29 (0.41)
Pasting Temperature (°C)	78.3 (1.6)	76.8 (1.3)	78 (2)	78 (2)	76 (2)	78 (2)	77.0 (1.1)
Starch	**Mean (SD) of yellow pea**						**5-year**
Characteristics	**2020**	**2019**	**2018**	**2017**	**2016**	**2015**	**Mean (SD)**
Peak Viscosity (RVU)	132 (15)	148 (14)	140 (14)	140 (12)	145 (27)	140 (19)	143 (4)
Hot Paste Viscosity (RVU)	122 (13)	133 (10)	131 (12)	130 (10)	132 (19)	130 (15)	131 (1)
Breakdown (RVU)	13 (5)	16 (6)	9 (5)	10 (5)	13 (10)	10 (5)	12 (3)
Cold Paste Viscosity (RVU)	223 (34)	240 (27)	238 (29)	233 (28)	249 (60)	234 (39)	239 (6)
Setback (RVU)	101 (23)	110 (20)	108 (19)	103 (20)	117 (44)	104 (26)	108 (6)
Peak Time (Minute)	5.29 (0.48)	5.17 (0.35)	5 (1)	5 (1)	5 (1)	5 (1)	5.07 (0.13)
Pasting Temperature (°C)	77.2 (1.7)	76.2 (1.3)	77 (2)	78 (2)	75 (4)	76 (4)	76.4 (1.1)
Starch	**Mean (SD) of winter pea**						**5-year**
Characteristics	**2020**	**2019**	**2018**	**2017**	**2016**	**2015**	**Mean (SD)**
Peak Viscosity (RVU)	126 (11)	134 (19)	**	**	**	**	nd
Hot Paste Viscosity (RVU)	113 (12)	118 (8)					nd
Breakdown (RVU)	13 (2)	16 (13)	**	**	**	**	nd
Cold Paste Viscosity (RVU)	216 (33)	209(35)	**	**	**	**	nd
Setback (RVU)	103 (22)	92 (28)					
Peak Time (Minute)	5.18 (0.17)	5.58 (0.91)					
Pasting Temperature (°C)	78.8 (1.4)	77.5 (1.5)	**	**	**	**	nd
Starch	**Mean (SD) of marrowfat pea**						**5-year**
Characteristics	**2020**	**2019**	**2018**	**2017**	**2016**	**2015**	**Mean (SD)**
Peak Viscosity (RVU)	103 (14)	149 (0)	**	**	**	**	nd
Hot Paste Viscosity (RVU)	100 (12)	136 (0)					nd
Breakdown (RVU)	3 (2)	13 (0)	**	**	**	**	nd
Cold Paste Viscosity (RVU)	158 (21)	224 (0)	**	**	**	**	nd
Setback (RVU)	58 (9)	88 (0)					
Peak Time (Minute)	5.37 (0.05)	5.33 (0)					
Pasting Temperature (°C)	79.9 (1.0)	77.4 (0)	**	**	**	**	nd

**not previously reported; nd = not determined

Table 14. Mean starch characteristics of dry pea cultivars grown in the USA in 2020.

Market Class	Cultivar	Peak Viscosity (RVU)	Hot Paste Viscosity (RVU)	Breakdown (RVU)	Cold Paste Viscosity (RVU)	Setback (RVU)	Peak Time (Min)	Pasting Temperature (°C)
Green	AAC Comfort*	158	143	15	280	137	5.20	78.4
	Aragorn	142	128	14	246	118	5.17	77.9
	Arcadia	148	134	14	261	127	5.24	78.1
	Ariel*	157	133	24	227	94	5.27	79.1
	Banner	118	109	9	189	80	5.50	79.8
	Bluemoon	131	127	4	265	138	5.34	78.1
	CDC Greenwater*	128	120	8	219	99	5.20	77.6
	Cruiser	157	141	16	276	135	5.20	78.3
	Daytona	137	128	9	256	128	5.16	76.5
	Empire	132	125	7	241	116	5.40	77.5
	Fairway	131	120	11	213	93	5.34	80.3
	Ginny	131	120	11	224	104	5.40	79.6
	Greenwood	142	133	9	267	135	5.18	76.2
	Hampton	132	121	10	206	85	5.17	77.8
	Majoret	139	129	10	251	123	5.20	77.9
	Shamrock	139	133	6	233	100	5.34	78.0
	Striker*	124	112	12	200	89	5.07	77.6
	Viper	163	144	19	288	144	5.20	78.3
Yellow	AAC Carver	127	120	7	226	106	5.30	76.6
	AAC Chrome*	134	122	12	214	92	5.20	77.5
	AAC Profit	141	132	9	259	126	5.21	77.0
	AC Agassiz*	136	125	11	245	120	5.00	78.4
	AC Earlystar	145	139	6	269	130	5.31	76.2
	Blaze	103	99	4	176	77	6.98	79.6
	Bridger*	120	118	2	217	98	5.93	78.3
	CDC Amarillo	132	117	15	201	84	5.05	76.7
	CDC Golden	125	121	4	227	106	6.10	78.7
	CDC Inca	142	126	16	222	96	5.04	76.8
	CDC Meadow*	138	121	18	229	108	4.93	76.7
	CDC Saffron*	127	122	5	207	85	5.20	75.9
	CDC Spectrum*	134	125	9	236	112	5.13	77.6
	Delta*	145	135	10	254	119	5.27	76.8
	DL Apollo*	126	115	11	225	110	5.00	77.6
	DS Admiral*	133	121	12	232	111	5.00	76.7
	Durwood	126	119	8	211	93	5.30	76.8
	Hyline	151	137	14	263	125	5.00	77.5
	Jetset*	139	126	13	220	94	5.13	77.6
	Korando	128	117	11	193	76	5.10	77.0
	LG Amigo*	132	123	9	214	91	5.13	77.6
	LG Sunrise*	136	120	16	243	123	4.93	75.8
	Montech*	126	121	5	212	91	5.53	78.4
	ND Dawn	136	127	9	241	113	5.29	77.9
	Nette 2010	131	123	9	226	103	5.07	76.3
	Pizzaz*	139	134	5	235	101	5.60	79.2
	Puris PP0667	155	142	13	271	129	5.25	77.0
	Salamanca	122	113	10	202	89	5.16	77.0
	Spider	140	126	14	217	91	5.13	77.6
	Treasure	137	129	8	249	120	5.27	77.2
	Yellowstone*	147	138	9	249	111	5.53	78.3
Winter	Goldenwood*	140	129	11	257	129	5.13	80.0
	Vail	121	108	13	202	95	5.20	78.4
Marrowfat	145-22*	113	108	5	173	65	5.40	79.3
	90-7*	93	91	2	143	52	5.33	80.6

*Only one sample of cultivar tested

Lentil Quality

A total of 91 lentil samples were collected from Idaho, Montana, North Dakota and Washington between August and November 2020. Growing location, number of samples, color, and cultivar details of lentil samples can be found in Table 15. Pardina represented all 22 samples of the Spanish brown lentils. For green lentil, CDC Richlea accounted for 22 of the 59 samples while 9 samples of both Avondale and Brewer cultivars were evaluated. Redchief (4) and CDC Maxim (4) were the most common red lentil evaluated for the survey.

Table 15. Description of lentils used in the 2020 pulse quality survey.

State	No. of Samples	Market Class	Cultivars
Idaho	16	Green	Brewer
		Red	Redchief
		Spanish Brown	Pardina
Montana	21	Green	Avondale
			CDC Greenstar
			CDC Impress
			CDC Kermit
			CDC Richlea
			CDC Viceroy
			Sage
		Red	CDC Impala
		Spanish Brown	Pardina
North Dakota	30	Green	Avondale
			CDC Greenstar
			CDC Imvincible
			CDC Richlea
			CDC Viceroy
		Red	CDC Maxim
			CDC Redmoon
Washington	24	Green	Brewer
			Merrit
		Spanish Brown	Pardina

Proximate composition of lentils

(Tables 16-18)

Moisture

The moisture content of lentils ranged from 6.2 to 10.4% in 2020 (Table 16). The mean moisture content (8.2%) was slightly lower than the 5-year mean of 8.6% and was most similar to the mean moisture value of lentils from 2018, but lower than lentils from other years. Overall, all samples evaluated had moisture contents below the 13-14% recommended general storability. The moisture contents of the different market classes were between 7.5 and 8.8% (Table 17). The green lentils had a mean moisture content of 8.5% while red and Spanish brown lentils had moisture contents of 7.9 and 7.5%, respectively. The green lentils from 2020 had lower moisture contents than the five previous years and was 1.1 percentage points lower than the 5-year mean moisture content. The 2020 red lentils had lower moisture contents than lentils from the previous five years except for lentils from 2018. The 5-year mean moisture content was 1 percentage unit higher than the lentils from 2020. Spanish brown lentils had a mean moisture content that was comparable to lentil from 2016 and 2018, but lower than lentils from other harvest years. The highest moisture contents were observed in the CDC Redmoon (10.1%) cultivar (i.e., red lentil) while Brewer (7.0%) and Redchief (6.9%) cultivars in the green and red market classes had the lowest moisture contents (Table 18).

Ash

Ash content of lentils ranged from 1.6 to 4.1% with a mean of 2.6% (Table 16). The mean ash content of lentils grown in 2020 was the same as the 5-year mean of 2.6%. Ash content is a general indicator of minerals present. Furthermore, the ash contents remain relatively constant over the last 5 years. The mean ash contents of the green, red and Spanish brown market classes were 2.5, 2.7 and 2.6%, respectively (Table 17). The Sage and CDC Imvincible had the lowest (2.3%) and highest (2.5%) mean ash content of the green lentils, respectively. The Sage (green) cultivar also had the lowest (2.0%) ash content in 2019. CDC Redmoon (red) cultivar had a mean ash content of 3.3% (Table 18).

Fat

Fat content of lentils ranged from 0.2 to 2.4% with a mean of 1.3% (Table 16). The fat content was measured in 2017 for the first time; thus, no 5-year mean value is available. However, lentils from the 2017 (2.1%) and 2018 (2.6%) harvest years were both higher than the mean fat content from 2020. Literature reports indicate that lentils have fat contents between 1 and 3%; therefore, the fat content of most of the lentils grown in 2020 fall at the lower end of the range reported by others. No difference in fat percentages were observed between the green and red market classes while the Spanish brown lentils had slightly higher fat contents among the different market classes (Table 17). Merrit (green) cultivar had the highest mean (1.7%) fat content while CDC Impress (Green) had the lowest (0.8%) fat content among cultivars (Table 18).

Protein

Protein content of lentils ranged from 18.4 to 28.3% with a mean value of 24.8%. The mean protein content of lentils grown in 2020 was higher than lentils grown in 2015-2019 (i.e., 22.6-24.4%) and the 5-year mean value of 23.4%. The protein contents of the three market classes were different (Table 17). Red lentils had the highest mean protein content (26.3%) among lentil market classes while the Green and Spanish brown lentils had mean protein values of 24.5 and 24.9%, respectively. The Redchief (red) and Sage (green) cultivars had the highest and lowest protein percentage, respectively, among known cultivars (Table 18).

Total starch

Total starch content of lentils ranged from 38.5 to 50.5%, with a mean of 44.4% (Table 16). The mean total starch percentage of lentils grown in 2020 was higher than starch percentage in lentils from the previous five years and the 5-year mean value. However, the mean starch content for lentils from 2020 was comparable lentils from 2017 and 2018.

The mean starch contents of the lentils in the red and Spanish brown market classes were 43.6 and 43.9%, respectively, while lentils in the green market class had a mean starch content of 44.7% (Table 17). The mean starch percentage for green lentil from 2020 was most comparable to lentils from 2017 and 2018 but higher than lentils from other harvest years. Lentils from the red market class in 2020 tended to have higher percent starch than lentils from other harvest years except the 2016 crop years (Table 17). The Spanish brown lentils had total starch percentages that were similar to lentils from 2017 and 2019 but slightly lower than lentils from 2018.The starch percentage in Spanish brown lentils was 2% points higher than the 5-year mean starch value. The highest mean starch content was observed in CDC Impala (red) cultivar at 50.5% (Table 18). The Brewer (41.0%) and Redchief (41.1%) cultivars had the lowest mean starch content among known cultivars tested (Table 18).

Table 16. Proximate composition of lentils grown in the USA, 2015-2020.

Proximate Composition (%)	2020		Mean 2019	2018	2017	2016	2015	5-year
	Range	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Moisture	6.2-10.4	8.2 (1.2)	9.8 (1.6)	8.4 (1.1)	8.8 (1.0)	9.0 (1.0)	9.7 (1.0)	8.6 (1.2)
Ash	1.6-4.1	2.6 (0.4)	2.4 (0.3)	2.6 (0.3)	2.5 (0.2)	2.5 (0.2)	2.7 (0.3)	2.6 (0.1)
Fat	0.2-2.4	1.3 (0.5)	1.1 (0.3)	2.6 (0.8)	2.1 (0.5)	*	*	nd
Protein	18.4-28.3	24.8 (1.5)	24.3 (1.5)	24.4 (1.9)	23.5 (1.7)	21.7 (1.6)	22.6 (1.2)	23.4 (1.1)
Total Starch	38.5-50.5	44.4 (2.8)	42.8 (1.6)	44.0 (2.9)	44.0 (2.0)	43.3 (3.1)	38.3 (2.7)	42.4 (2.5)

*= not reported; nd = not determined

Table 17. Proximate composition of different market classes of lentils grown in the USA, 2015-2020.

Market Class	Proximate Composition (%)	Mean (SD) 2020	2019	2018	2017	2016	2015	5-Year Mean (SD)
Green	Moisture	8.5 (1.2)	10.3 (1.8)	8.8 (1.1)	9.0 (0.8)	9.2 (0.9)	9.8 (1)	9.4 (0.6)
	Ash	2.5 (0.5)	2.4 (0.2)	2.6 (0.4)	2.4 (0.2)	2.5 (0.2)	2.9 (0.2)	2.6 (0.2)
	Fat	1.3 (0.5)	1.1 (0.4)	2.8 (0.8)	2.1 (0.5)	*	*	nd
	Protein	24.5 (1.6)	24.8 (1.5)	24.2 (2.0)	23.2 (1.7)	21.4 (1.5)	22.5 (1)	23.2 (1.3)
	Total Starch	44.7 (2.9)	42.1 (1.4)	44.1 (3.4)	44.0 (2.1)	43.3 (3.2)	38.5 (2)	42.4 (2.3)
Red	Moisture	7.9 (1.2)	8.8 (1.0)	7.6 (1.1)	8.6 (1.2)	9.3 (0.8)	10.4 (1)	8.9 (1.0)
	Ash	2.7 (0.3)	2.4 (0.3)	2.8 (0.1)	2.5 (0.2)	2.6 (0.2)	2.7 (0.4)	2.6 (0.2)
	Fat	1.3 (0.4)	1.2 (0.3)	2.1 (0.3)	2.0 (0.5)	*	*	nd
	Protein	26.3 (0.9)	24.7 (0.8)	26.0 (0.6)	24.3 (1.5)	23.3 (1.2)	22.8 (2)	24.2 (1.3)
	Total Starch	43.6 (4.1)	42.8 (0.7)	42.8 (1.2)	43.9 (2.0)	44.9 (1.8)	39.1 (2)	42.7 (2.2)
Spanish Brown	Moisture	7.5 (0.8)	9.8 (1.2)	7.8 (0.8)	8.2 (0.7)	7.8 (0.7)	8.9 (1)	8.5 (0.9)
	Ash	2.6 (0.1)	2.4 (0.3)	2.6 (0.2)	2.7 (0.2)	2.5 (0.3)	2.9 (0.2)	2.6 (0.2)
	Fat	1.6 (0.4)	1.1 (0.2)	2.0 (0.5)	2.2 (0.5)	*	*	nd
	Protein	24.9 (0.9)	23.5 (1.2)	24.3 (1.4)	23.6 (1.2)	20.7 (1.0)	22.8 (1)	23.0 (1.4)
	Total Starch	43.9 (1.8)	43.9 (1.5)	44.4 (1.2)	43.9 (1.7)	41.1 (2.8)	36.8 (4)	42.0 (3.2)

*= not reported; nd = not determined

Physical parameters of lentils (Tables 19-23)

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. The data presented includes the range and mean value for 2020 and comparisons to the 5-year mean values when applicable.

Test weight ranged from 60.1-67.5 lbs/bu with a mean of 64.3 lbs/bu. This mean value was slightly higher than the 5-year mean of 62 lbs/bu (Table 19). The test weight for all lentil samples harvested in 2020 was higher than lentils harvested in previous years. The mean test weight of lentils in the Spanish brown market class was approximately 2 percentage points higher than test weights of lentils from the green and red market classes (Table 20). The highest test weight of 67.5 lbs/bu was observed in CDC Impala and CDC Redmoon cultivars. The Merrit (61.7 lbs/bu) and Brewer (61.9 lbs/bu) had the lowest test weight values (Table 21). The Brewer cultivar also had the lowest mean test weight (59 lbs/bu) in 2019.

Table 18. Mean proximate composition of lentil cultivars grown in the USA in 2020.

Market Class	Cultivar	Concentration (%)				
		Moisture	Ash	Fat	Protein	Starch
Green	Avondale	9.4	2.5	1.2	23.6	46.3
	Brewer	7.0	2.8	1.6	26.3	41.0
	CDC Greenstar	9.7	2.9	1.6	23.8	45.2
	CDC Impress*	8.9	2.4	0.8	23.9	49.4
	CDC Imvincible*	9.8	3.3	1.1	26.2	44.7
	CDC Kermit*	8.8	2.5	1.0	24.1	45.9
	CDC Richlea	9.1	2.4	1.0	23.4	46.1
	CDC Viceroy	8.1	2.4	1.2	25.6	43.9
	Merrit	7.2	2.6	1.7	26.3	42.2
	Sage*	8.6	2.3	1.1	21.9	45.6
Red	CDC Impala*	8.7	2.4	1.5	25.2	50.5
	CDC Maxim	8.2	2.6	1.1	25.8	44.5
	CDC Redmoon*	10.1	3.3	0.9	26.1	43.0
	Redchief	6.9	2.8	1.5	27.1	41.1
Spanish Brown	Pardina	7.5	2.6	1.6	24.9	43.9

*Only one sample of cultivar tested

The range and mean **1000 seed weight** of lentils grown in 2020 were 30 to 70 g and 48.0 g, respectively (Table 20). The mean value was higher than the 5-year mean of 43 g. Lentils of the red market class had a mean 1000 seed weight of 43 g, which was higher than the 5-year mean of 37 g for red lentils. However, the mean 1000 seed weight for 2020 red lentils was most closely matched the 1000 seed weight of red lentils from the 2018 crop year. Lentils from the green market class had a mean 1000 seed weight of 51 g, which is higher than the 5-year mean value (Table 20). The 1000 seed weight for green lentils from 2020 were also higher than the mean 1000 seed weights from previous harvest years. Lentils in the Spanish brown market class had mean 1000 seed weight that was higher than the 5-year mean value and all previous years except 2016. CDC Imvincible (34 g), CDC Viceroy (34 g) and CDC Maxim (35 g) had the lowest 1000 seed weights. Merrit (65 g) had the highest 1000 seed weight (Table 21).

Water hydration capacity of lentils ranged from 42 to 190%, with a mean of 91% (Table 19). The 2020 mean water hydration capacity value was similar to lentils from 2016 and 2019, but lower in lentils from other harvest years. The water hydration capacity (126%) was highest for red lentils while the green (88%) and Spanish brown (81%) market classes had significantly lower water hydration capacities (Table 20). The water hydration capacities of green and Spanish brown lentils from 2020 were lower than the 5-year mean values from their respective classes. Spanish brown lentils had comparable water hydration capacity to lentils grown in 2016. Lentils from the red market class had a 2020 mean water hydration value that exceeded lentils from other harvest years. The water hydration capacity of the red lentils from 2020 was significantly higher than the 5-year mean. The mean water hydration capacity ranged from 71% in CDC Imvincible to 167% in CDC Maxim. Most other cultivars had water hydration capacities of approximately 90 to 100% (Table 21).

Table 19. Physical parameters of lentils grown in the USA, 2015-2020.

Physical Parameters	2020		2019	2018	2017	2016	2015	5-year
	Range	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Test Weight (lbs/bu)	60.1-67.5	64.3 (2)	62.4 (2.5)	62.9 (2.2)	62 (2)	62 (3)	62 (2)	62 (1)
1000 Seed Wt. (g)	30-70	48.0 (10)	42.8 (10.8)	42 (9)	44 (9)	45 (9)	43 (9)	43 (1)
Water Hydration Capacity (%)	42-190	91 (21.1)	91 (8)	99 (2)	101 (3)	91 (11)	118 (7)	100 (11)
Unhydrated Seeds (%)	0-25	5 (6)	4 (4)	2 (3)	1 (2)	4 (7)	1 (1)	2 (2)
Swelling Capacity (%)	60-183	117 (21.4)	143 (15)	140 (15)	144 (28)	140 (28)	161 (33)	146 (9)
Cooked Firmness (N/g)	9.4-29.0	19.9 (4.3)	15.8 (4.8)	15 (3)	14.9 (3.9)	13.4 (2.5)	11.9 (2)	14 (2)

Table 20. Physical parameters of different market classes of lentils grown in the USA, 2015-2020.

Market class	Physical Parameter	2020	2019	2018	2017	2016	2015	5-Year Mean
Green	Test Weight (lbs/bu)	63.6 (1.8)	61.8 (2.4)	62.2 (1.8)	61 (2)	62 (2)	62 (2)	62 (0)
	1000 Seed Wt (g)	51 (10)	46 (12)	47 (8)	48 (8)	49 (8)	47 (9)	47 (1)
	Water Hydration Capacity (%)	88 (11)	93 (6)	100 (9)	103 (10)	95 (9)	121 (18)	113 (20)
	Unhydrated Seeds (%)	6 (7)	2 (2)	1 (1)	1 (1)	2 (4)	1 (1)	2 (1)
	Swelling Capacity (%)	117 (18)	145 (11)	140 (15)	144 (18)	148 (26)	148 (32)	137 (19)
	Cooked Firmness (N/g)	19.2 (4.2)	15.5 (5.3)	14.5 (3.8)	15.1 (4.4)	13.5 (2.8)	12.5 (2.0)	14.2 (1.0)
Red	Test Weight (lbs/bu)	63.9 (2.5)	64.2 (0.4)	61.6 (2.1)	63 (3)	63 (4)	64 (1)	63 (1)
	1000 Seed Wt (g)	43 (9)	36.8 (6)	41 (5)	36 (6)	36 (3)	36 (2)	37 (2)
	Water Hydration Capacity (%)	126 (41)	84 (8)	106 (12)	95 (16)	87 (3)	98 (9)	105 (21)
	Unhydrated Seeds (%)	5 (6)	8 (1)	1 (1)	2 (2)	4 (3)	2 (1)	3 (3)
	Swelling Capacity (%)	138 (35)	140 (5)	143 (15)	132 (11)	125 (21)	155 (15)	139 (11)
	Cooked Firmness (N/g)	21.7 (5.3)	14.8 (5.7)	15.2 (3.5)	14.9 (2.2)	13.2 (2.1)	12.0 (1.0)	14.0 (1.0)
Spanish Brown	Test Weight (lbs/bu)	66.1 (1.0)	62.4 (2.0)	65.4 (0.6)	64 (2)	66 (1)	64 (2)	64 (1)
	1000 Seed Wt (g)	42 (4)	43 (7)	32 (2)	40 (10)	36 (2)	38 (8)	38 (4)
	Water Hydration Capacity (%)	81 (13)	91 (8)	93 (10)	102 (15)	79 (16)	124 (6)	98 (17)
	Unhydrated Seeds (%)	5 (4)	3.9 (6)	6 (3)	3 (4)	13 (13)	1 (1)	5 (5)
	Swelling Capacity (%)	109 (15)	143 (21)	137 (16)	144 (18)	118 (26)	191 (23)	147 (27)
	Cooked Firmness (N/g)	21.7 (3.9)	15.8 (2.8)	15.5 (1.8)	13.6 (3.3)	13.1 (0.8)	10.8 (1.3)	13.8 (2.0)

Table 21. Mean physical parameters of lentil cultivars grown in the USA in 2020.

Market Class	Cultivar	Test Weight (lbs/bu)	1000 Seed Wt (g)	Water Hydration Capacity (%)	Unhydrated Seeds (%)	Swelling Capacity (%)	Cooked Firmness (N/g)
Green	Avondale	63.5	49	91	3	124	17.9
	Brewer	61.9	60	93	0	115	22.6
	CDC Greenstar	62.4	64	99	2	129	18.0
	CDC Impress*	65.0	53	93	2	134	19.1
	CDC Imvincible*	66.8	34	71	25	90	16.0
	CDC Kermit*	66.5	36	88	8	106	13.2
	CDC Richlea	63.5	51	87	7	118	19.9
	CDC Viceroy	66.6	34	76	15	99	15.8
	Merrit	61.7	65	95	0	124	20.0
	Sage*	66.5	42	89	8	117	15.2
Red	CDC Impala*	67.5	36	86	11	92	14.4
	CDC Maxim	64.8	35	167	5	161	23.3
	CDC Redmoon*	67.5	41	77	20	100	13.2
	Redchief	61.3	52	107	0	136	20.5
Spanish Brown	Pardina	66.1	42	81	5	109	21.7

*Only one sample of cultivar tested

Unhydrated seed percentage ranged from 0 to 25% with a mean of 5%, which is more than the 5-year mean of 2% (Table 19). The mean unhydrated seed percentage was higher due to the presence of seven samples with unhydrated seed levels of greater than 20%. The amount of unhydrated seeds in all market classes varied from 5 to 6% (Table 20). The green lentils from 2020 had mean unhydrated seed percentage that were higher than the green lentils from each of the years between 2015 and 2019. Spanish brown lentils had similar unhydrated seed values compared to the five-year mean values. The unhydrated seed count in the red lentils was slightly higher than the 5-year mean unhydrated seed percentage. Several cultivars had no unhydrated seed percentage while the CDC Imvincible cultivar had the highest at 25% (Table 21).

The **swelling capacity** of all lentils ranged from 60 to 183%, with a mean value of 117% (Table 19). The mean swelling capacity from 2020 samples were significantly lower than that of lentils from the previous years, including the 5-year mean swelling capacity. The swelling capacity of lentils was similar between the green and Spanish brown market classes with green lentils having a slightly higher swelling capacity (Table 20). However, the red market class had the highest swelling capacity at 138%. Swelling capacities of the green and Spanish brown lentils were lower than their respective 5-year mean samples. In contrast, the swelling capacity of the Red lentils was similar to the 5-year mean swelling capacity (Table 20). CDC maxim had the greatest swelling capacity (161%) while CDC Imvincible had the lowest (90%) among all cultivars (Table 21). The swelling capacity of pulses is generally affected by water uptake by the seed. Thus, the low swelling capacity for CDC Imvincible lentils was likely due to the low water uptake as supported by the high number of unhydrated seeds and low water hydration capacity. These observations are reflected in other cultivars with low swelling capacities.

The **cooked firmness** of all lentils ranged from 9.4 to 29.0 N/g with a mean value of 19.9 N/g (Table 19). The lentils from 2020 had slightly greater cooked firmness values than lentils from 2019 but significantly greater values than lentils from the other harvest years. Although the cooked firmness of lentils was not substantially different between the market classes, the green lentils did have the lowest cooked firmness (Table 20). Regardless of the market class, the cooked firmness was higher in lentils harvested in 2020 compared to other harvest years, including the 5-year mean. Among the cultivars, CDC maxim (red) had the highest cooked firmness value while CDC Redmoon (red) and CDC Kermit (green) had the lowest cooked firmness (Table 21).

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 22). Color quality for all lentils in 2020 indicated that the lentils had higher L* values than in lentils from previous years except 2015. This data indicates that the lentils from the 2020 crop year were lighter in color than those from previous years. The lower a* value (i.e., green-red scale) in the green lentil indicates a less red color while a more negative a* value for the green lentils indicates a greener color. In 2020, the a* value of 0.83 indicates that the lentils were greener in 2020 compared to lentils from other harvest years except 2019. In the red lentil market class, the 2020 samples were less red based on the lower a* value compared to red lentils from previous years. The lentils also had a lower b* value suggesting the samples are less yellow in nature and would have a darker red color compared to sample that had higher b* values (Table 22). The Spanish brown a* value was lower in the 2020 samples compared to brown lentils from all other years; therefore, indicating less redness in the sample.

The color of the lentils changed after the soaking process. Green and Spanish brown market classes became lighter as evidenced by the higher L* values (Table 22) compared to pre-soaked lentils. However, the lightness value remained unchanged in the red market class after soaking. In the green market class, the decreased a* value indicated an increase in greenness of the lentils after soaking. In the red lentil market class, a* increased suggesting more redness was observed in lentil after soaking, this same trend occurred in previous years. The Spanish brown redness value decreased upon soaking of the lentils. Lentils from all market classes became more yellow (i.e., increased b value) after soaking. The color difference in lentil samples was the greatest for the green market class and the least for the Spanish brown market class (Table 22). Overall, the colors were less impacted by soaking in comparison to lentils from previous years based on the smaller color difference values compared to lentils from other harvest years.

Table 22. Color quality of lentils grown in the USA before and after soaking, 2015-2020.

Color Scale[#]	Mean (SD) of green lentils											
	Before Soaking						After Soaking					
	2020	2019	2018	2017	2016	2015	2020	2019	2018	2017	2016	2015
L* (lightness)	59.75 (1.45)	48.07 (1.91)	53.97 (3.25)	56.13 (2.29)	55.22 (1.19)	57.14 (5.76)	60.15 (3.93)	52.93 (1.52)	57.69 (1.36)	57.26 (2.1)	58.23 (2.01)	62.29 (1.18)
a* (green-red)	0.83 (1.05)	0.53 (1.43)	4.34 (1.21)	5.32 (1.15)	4.69 (1.42)	2.49 (2.17)	-0.12 (4.00)	-0.98 (2.86)	3.86 (1.34)	4.71 (1.24)	4.06 (1.42)	0.59 (1.79)
b* (blue-yellow)	15.39 (0.95)	13.54 (3.45)	21.28 (1.51)	22.11 (1.46)	23.16 (1.38)	19.55 (5.02)	20.48 (5.52)	20.48 (2.35)	30.73 (2.39)	31.98 (2.60)	32.30 (2.60)	28.30 (1.62)
Color Difference	8.23 (4.79)	9.31 (3.40)	10.54 (3.35)	10.42 (1.85)	9.82 (1.96)	6.18 (1.62)						
Color Scale	**Mean (SD) of red lentils**											
	Before Soaking						**After Soaking**					
	2020	**2019**	**2018**	**2017**	**2016**	**2015**	**2020**	**2019**	**2018**	**2017**	**2016**	**2015**
L* (lightness)	55.13 (2.32)	44.84 (2.08)	51.13 (4.17)	46.19 (3.87)	45.95 (1.70)	56.84 (5.35)	55.05 (3.93)	48.83 (2.48)	53.01 (3.24)	48.95 (3.12)	49.54 (0.75)	52.51 (0.60)
a* (green-red)	2.88 (1.91)	3.38 (0.60)	7.38 (0.50)	7.40 (1.28)	7.97 (0.63	3.71 (1.63)	5.36 (3.42)	9.35 (1.84)	13.63 (1.12)	12.63 (2.99)	13.84 (1.08)	8.64 (0.22)
b* (blue-yellow)	11.07 (4.09)	9.36 (1.49)	21.28 (1.51)	13.93 (2.82)	14.34 (1.34)	18.58 (4.60)	14.67 (2.55)	19.05 (2.52)	28.44 (2.11)	28.18 (2.89)	27.04 (1.85)	20.29 (1.45)
Color Difference	7.40 (3.28)	12.12 (1.96)	13.02 (3.76)	15.89 (2.89)	14.51 (2.04)	6.37 (2.22)						
Color Scale	**Mean (SD) of brown lentils**											
	Before Soaking						**After Soaking**					
	2020	**2019**	**2018**	**2017**	**2016**	**2015**	**2020**	**2019**	**2018**	**2017**	**2016**	**2015**
L* (lightness)	51.97 (0.33)	39.52 (2.39)	42.71 (6.78)	44.59 (3.55)	42.92 (1.12)	55.71 (5.26)	53.96 (0.44)	39.03 (3.65)	49.42 (1.75)	48.84 (3.04)	47.88 (1.69)	51.21 (2.82)
a* (green-red)	0.66 (1.48)	1.72 (0.58)	5.01 (0.63)	6.11 (1.02)	5.21 (0.20)	3.43 (2.79)	-0.90 (0.70)	2.93 (1.25)	7.08 (0.39)	7.66 (1.04)	6.59 (0.45)	4.66 (0.69)
b* (blue-yellow)	8.60 (1.58)	6.48 (1.63)	12.35 (1.57)	13.18 (2.50)	12.07 (0.94)	17.95 (4.79)	10.13 (1.54)	14.69 (1.34)	29.33 (2.55)	28.52 (3.85)	26.59 (1.31)	19.54 (1.84)
Color Difference	3.53 (1.79)	8.72 (1.03)	19.01 (5.74)	16.16 (4.43)	15.56 (1.12)	5.25 (1.06)						

[#]color scale L* (lightness) axis – 0 is black and 100 is white; a* (green-red) axis – positive values are red, negative values are green, and zero is neutral; and b* (blue-yellow) axis – positive values are yellow, negative values are blue, and zero is neutral. Color difference = change in value before soaking and after soaking.

Among the cultivars, Pardina had the lowest L* value followed by CDC Impala (Table 23). The highest L* was observed in the CDC Impress green lentil. This follows expectations that the brown and red lentils would be darker than the green lentils. Except for the Brewer, Merrit and Redchief lentils, the L* values of lentil increased after soaking with CDC Imvincible having the highest values (Table 23). The green lentil cultivar became greener (i.e., reduction of the a* value) after soaking while the red intensity (increased a* value) of the red cultivars increased during soaking. Sage had the greenest color after soaking while CDC Maxim had the highest red value. In 2019, Sage also had the greenest color after soaking. The b* value increased substantially in all lentils during soaking except for Brewer, Merrit and Redchief. The green lentil cultivar CDC Impress 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 CDC Impala cultivar (Table 23). The increase in redness and yellowness during soaking likely contributed to the greatest color difference in this cultivar. The color of Pardina was the most stable as this cultivar had the lowest color difference value (i.e., 3.53).

Table 23. Color quality of USA lentil cultivars before and after soaking, 2020.

		Mean Color Values[#]						
		Before Soaking			After Soaking			Color
Market Class	Cultivar	L*	a*	b*	L	a*	b*	Difference
Green	Avondale	59.76	0.75	15.39	61.22	-0.70	23.90	8.82
	Brewer	58.09	1.27	15.77	56.36	-0.70	12.21	4.68
	CDC Greenstar	60.38	1.36	15.81	61.44	-0.16	25.04	9.42
	CDC Impress**	61.55	1.73	16.26	63.92	0.18	26.64	10.78
	CDC Imvincible**	60.58	0.06	16.06	64.88	-0.78	22.79	8.03
	CDC Kermit**	60.97	0.35	15.77	62.67	-1.32	25.24	9.80
	CDC Richlea	60.68	0.75	15.47	60.69	-0.87	23.10	9.98
	CDC Viceroy	59.33	0.10	14.90	62.75	-1.06	22.22	8.44
	Merrit	58.49	1.53	14.68	56.61	-0.43	11.55	4.54
	Sage**	59.78	-0.41	14.96	62.26	-1.46	25.33	10.73
Red	CDC Impala**	52.53	3.83	6.86	54.35	8.19	17.44	11.59
	CDC Maxim	53.79	4.11	7.79	53.82	8.33	16.99	10.13
	CDC Redmoon**	52.81	5.52	9.77	57.64	6.25	12.35	5.59
	Redchief	57.70	0.75	15.73	55.81	1.46	12.25	4.06
Spanish Brown	Pardina	51.97	0.66	8.60	53.96	-0.90	10.13	3.53

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

Pasting properties

(Tables 24-26)

Peak viscosity, and hot paste viscosities and breakdown values of lentils grown in 2020 were comparable to lentils from the 2017 and 2018 harvest years. Cold paste viscosity of lentils from 2020 was similar to cold paste viscosities of lentils from 2016 (Table 24). Mean peak time for lentils in 2020 was almost identical to the 5-year mean value. Pasting temperature ranged from 75.9 to 83.2 °C, with a mean value of 78.9 °C, which is higher than the pasting temperatures of lentils from previous years. The peak, hot paste and cold paste viscosities were similar among the green and Spanish brown market classes (Table 25). In contrast, the peak, hot paste and cold paste viscosities obtained for lentils in the red market class were lower compared to the lentils in the other market classes. This suggests a thinner final viscosity for red lentil flours. Pasting characteristics for the green market class in 2020 were higher than the 5-year mean sample, suggesting that the lentils from 2020 produce thicker pastes and gels. In contrast, pasting characteristics for the red and Spanish brown market classes were slightly lower to 5-year mean values, indicating slightly thinner pastes and gels.

Variability in pasting characteristics were observed among cultivars (Table 26). In the green market class, the variability among cultivars was noticeable. Merrit had the lowest peak (114 RVU), hot paste (110 RVU), and cold paste (193 RVU) viscosities among the green lentil cultivars. In contrast, CDC Kermit had the highest peak (191 RVU) and hot paste (177 RVU) viscosities while Sage had the highest cold paste (328 RVU) viscosity (Table 26). In 2019, Sage also had the highest cold paste viscosity. CDC Impala had the highest peak (150 RVU), hot paste (142 RVU), and cold paste (278 RVU) viscosities among the red lentil cultivars in 2020. In contrast, redchief had the lowest peak (109 RVU), hot paste (107 RVU), and cold paste (179 RVU) viscosities. Overall, Pardina lentils had viscosity values that were in the mid-range of the distribution among individual cultivars.

Table 24. Starch characteristics of lentils grown in the USA, 2015-2020.

Starch Characteristic	2020 Range	2020 Mean (SD)	2019 Mean	2018 Mean	2017 Mean	2016 Mean	2015 Mean	5-year Mean (SD)
Peak Viscosity (RVU)	86-191	142 (21)	146 (14)	142 (18)	143 (17)	148 (20)	124 (17)	141 (10)
Hot Paste Viscosity (RVU)	85-177	133 (17)	137 (11)	134 (14)	136 (15)	133 (18)	119 (15)	132 (7)
Breakdown (RVU)	0-22	9 (6)	9 (6)	8 (6)	7 (4)	15 (6)	4 (4)	9 (4)
Cold Paste Viscosity (RVU)	151-328	237 (35)	253 (28)	245 (29)	253 (28)	239 (31)	205 (25)	239 (20)
Setback (RVU)	60-182	104 (21)	117 (19)	111 (16)	117 (16)	106 (16)	86 (13)	107 (13)
Peak Time (Minute)	4.87-7.00	5.68 (0.62)	5.49 (0.52)	5.85 (0.76)	5.65 (1)	5.16 (0.26)	6 (1)	5.63(0.33)
Pasting Temperature (°C)	75.9-83.2	78.9 (1.5)	77.1 (1.2)	77.8 (1.8)	77.8 (2)	75.9 (1.0)	77 (3)	77.1 (0.8)

Table 25. Starch characteristic of different market classes of lentils grown in the USA, 2015-2020.

Market class	Physical Parameter	Mean (SD) 2020	2019	2018	2017	2016	2015	5-Year Mean (SD)
Green	Peak Viscosity (RVU)	146 (21)	142 (13)	145 (18)	146 (16)	149 (22)	127 (17)	142 (9)
	Hot Paste Viscosity (RVU)	135 (17)	133 (8)	134 (14)	138 (13)	132 (20)	121 (14)	132 (6)
	Breakdown (RVU)	10 (6)	8 (5)	10 (6)	8 (5)	17 (6)	6 (5)	10 (4)
	Cold Paste Viscosity (RVU)	241 (35)	242 (26)	248 (30)	256 (5)	237 (35)	208 (25)	238 (18)
	Setback (RVU)	106 (22)	109 (19)	113 (17)	118 (16)	105 (18)	87 (14)	106 (12)
	Peak Time (Minute)	5.54 (0.55)	5.53 (0.54)	5.59 (0.16)	5.58 (0.47)	5.10 (0.20)	6 (1)	5.56 (0.32)
	Pasting Temperature (°C)	78.7 (1.6)	76.8 (1.5)	77.3 (2.0)	77.7	76.0 (1.0)	77 (4)	77.0 (1)
Red	Peak Viscosity (RVU)	130 (21)	148 (9)	122 (8)	134 (19)	141 (13)	112 (23)	131 (14)
	Hot Paste Viscosity (RVU)	123 (17)	134 (6)	121 (8)	129 (17)	132 (14)	108 (20)	125 (11)
	Breakdown (RVU)	7 (6)	14 (7)	1 (0)	5 (4)	9 (3)	4 (3)	7 (5)
	Cold Paste Viscosity (RVU)	218 (39)	249 (13)	214 (17)	241 (32)	238 (18)	190 (33)	226 (24)
	Setback (RVU)	95 (23)	115 (12)	93 (9)	112 (19)	106 (12)	82 (15)	102 (14)
	Peak Time (Minute)	5.77 (0.53)	5.37 (0.36)	6.57 (0.65)	5.85 (0.65)	5.47 (0.24)	6 (1)	5.85 (0.48)
	Pasting Temperature (°C)	79.0 (1.8)	78.0 (0.7)	79.0 (1.3)	78.1 (1.4)	75.9 (1.2)	76 (1)	77.4 (1.4)
Spanish Brown	Peak Viscosity (RVU)	139 (21)	153 (13)	143 (15)	150 (12)	148 (14)	123 (10)	143 (12)
	Hot Paste Viscosity (RVU)	132 (18)	143 (10)	139 (12)	144 (10)	135 (17)	121 (10)	136 (9)
	Breakdown (RVU)	6 (5)	9 (6)	5 (3)	6 (3)	14 (4)	2 (1)	7 (5)
	Cold Paste Viscosity (RVU)	235 (33)	249 (26)	253 (22)	264 (19)	247 (26)	210 (20)	245 (20)
	Setback (RVU)	102 (16)	129 (18)	114 (11)	120 (11)	113 (12)	89 (11)	113 (15)
	Peak Time (Minute)	6.03 (0.70)	5.45 (0.58)	6.19 (0.84)	5.59 (0.27)	5.13 (0.26)	6 (1)	5.67 (0.43)
	Pasting Temperature (°C)	79.5 (0.8)	77.4 (0.6)	78.2 (1.3)	78.0 (0.8)	75.7 (0.8)	79 (1)	77.7 (1.24)

Table 26. Mean starch characteristics of lentil cultivars grown in the USA in 2020.

Market Class	Cultivar	Peak Viscosity (RVU)	Hot Paste Viscosity (RVU)	Breakdown (RVU)	Cold Paste Viscosity (RVU)	Setback (RVU)	Peak Time (Min)	Pasting Temperature (°C)
Green	Avondale	148	137	11	243	106	5.15	77.7
	Brewer	123	119	4	209	90	5.87	80.6
	CDC Greenstar	151	140	11	253	113	5.54	78.8
	CDC Impress*	176	163	13	275	112	5.47	78.3
	CDC Imvincible*	158	145	13	253	108	5.40	77.6
	CDC Kermit*	191	177	14	289	112	6.40	78.4
	CDC Richlea	157	144	13	261	117	5.29	78.2
	CDC Viceroy	147	136	11	234	98	5.38	77.4
	Merrit	114	110	4	193	83	6.59	81.3
	Sage*	156	147	9	328	182	5.87	76.7
Red	CDC Impala*	150	142	8	278	136	6.13	79.1
	CDC Maxim	146	133	13	240	108	5.40	77.5
	CDC Redmoon*	136	130	5	224	93	5.80	77.6
	Redchief	109	107	2	179	73	6.05	81.0
Spanish Brown	Pardina	139	132	6	235	102	6.03	79.5

*Only one sample of cultivar tested

Chickpea Quality

Sample distribution

A total of 68 chickpea samples were collected from Idaho, Montana, North Dakota, and Washington between July and November 2020. Growing location, number of samples, market class, and genotype details of these dry chickpea samples are provided in Table 27. CDC Orion (10), and Sierra (18) accounted for the majority of the chickpea evaluated.

Table 27. Description of chickpea samples used in the 2020 pulse quality survey.

State	No. of Samples	Market Class	Cultivars	
Idaho	18	Kabuli	Bronic	Hammond
			Royal	Sierra
Montana	20	Desi	Myles	
		Kabuli	CDC Frontier	CDC Leader
			CDC Orion	CDC Palmer
			Kasin	Nash
			ND Crown	Royal
			Sawyer	Sierra
North Dakota	12	Kabuli	CDC Frontier	CDC Leader
			CDC Orion	ND Crown
			New Hope	
Washington	18	Kabuli	CDC Frontier	Dylan
			Nash	Pegasus
			Royal	Sawyer
			Sierra	Vega

Proximate composition of chickpea (Tables 28-29)

The **moisture content** of chickpeas ranged from 4.2 to 12.3% in 2020 (Table 28). The mean moisture content of the samples was 7.9%, which is lower than the 5-year mean of 9.3%. Chickpeas grown in 2020 had the lowest mean moisture content of any of the chickpea grown in previous years. Unlike 2019, no sample exceed the 13-14% moisture threshold for proper storage. New Hope had the highest moisture content at 9.2% among Kabuli chickpea while the Dylan cultivar had the lowest moisture (4.2%). The Myles cultivar (Desi chickpea) had a moisture content of 12.3%, which was the highest among all chickpea (Table 29). **Ash content** of chickpeas ranged from 2.0 to 4.3% with a mean of 3.0% (Table 28). The mean ash content of chickpeas grown in 2020 was comparable to ash contents of chickpea from the 2017 and 2018 harvest years. Hammond, Pegasus, and Royal had the lowest ash contents at 2.4% while New Hope had the highest mean ash content at 3.8% (Table 29). However, single samples of various cultivars had ash contents as high as 4.1%. The mean **fat content** was 5.4% and ranged from 4.0 to 6.7% (Table 28). Literature reports indicate that chickpea has a fat content between 2 and 7%; therefore, the fat content of chickpeas grown in 2020 fall within the range reported by others but less than the fat content recorded in previous years. The Desi cultivar Myles had the highest fat content at 6.4% while the Bronic cultivar had the highest (5.8%) fat contents among Kabuli chickpeas. Kasin had the lowest (4.0%) fat content (Table 29).

Protein content of chickpeas ranged from 15.2 to 25.3%, with a mean of 21.1% (Table 28). The mean protein content of chickpea grown in 2020 was higher than the 5-year mean protein content of 19.4%. The protein percentage (20.8%) from the 2018 harvested chickpea most closes matched the protein percentage of the chickpea harvested in 2020. Vega had the lowest (18.4%) protein content while Kasin had the highest protein content at 25.1% (Table 29).

Total starch content of chickpea ranged from 34.6 to 48.8%, with a mean of 40.8% (Table 28). The mean total starch content of chickpeas grown in 2020 was similar (i.e., 41%) to the mean starch content observed in chickpea from the 2018 harvest year and was slightly higher than the 5-year mean of 40.4%. The Kasin cultivar had the lowest (34.6%) starch content while the highest (48.8%) was observed in the CDC Palmer cultivar.

Table 28. Proximate composition of Kabuli chickpeas grown in the USA, 2015-2020.

	Year							
Proximate	2020		2019	2018	2017	2016	2015	5-year
Composition*	Range	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Moisture (%)	4.2-12.3	7.9 (1.1)	11.6 (2.6)	8.8 (0.9)	8.5 (0.9)	8.7 (1.7)	9 (1)	9.3 (1.3)
Ash (%)	2.0-4.3	3.0 (0.6)	2.6 (0.2)	2.8 (0.2)	2.8 (0.3)	2.7 (0.1)	2.7 (0.1)	2.7 (0.1)
Fat (%)	4.0-6.7	5.4 (0.6)	6.1 (0.5)	7.2 (1.1)	6.0 (0.4)	**	**	nd
Protein (%)	15.2-25.3	21.1 (2.0)	19.4 (1.9)	20.8 (2.3)	19.5 (2.0)	18.3 (1.4)	19 (1)	19.4 (0.9)
Starch (%)	34.6-48.8	40.8 (3.6)	40.1 (1.8)	41.1 (2.5)	39.6 (2.0)	40.0 (4.2)	41 (5)	40.4 (0.7)

*composition is on an "as is" basis;**not reported; nd= not determined

Physical parameters of chickpeas (Tables 30-33)

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 51.1-65.3 lbs/bu with a mean of 61.6 lbs/bu. This mean value is approximately the same as the 5-year mean of 61 lbs/bu (Table 30). The test weights of individual cultivars ranged from 58.6 lbs/bu in Dylan to 65.3 lbs/bu in the Kasin cultivars. Dylan also had the lowest test weight in 2019. The range and mean **1000 seed weight** of chickpeas grown in 2020 were 262-569 g and 417 g, respectively (Table 30). The mean 1000 seed weight was similar to the 5-year mean of 426 g. The Nash cultivar had a highest 1000 seed weight at 569 g while the Myles cultivar (Desi chickpea) had the lowest value at 171 g (Table 31). In 2019, Nash also had the highest 1000 seed weight.

Table 29. Mean proximate composition of chickpea cultivars grown in the USA, 2020.

Market		Concentration (%)				
Class	Cultivar	Moisture	Ash	Fat	Protein	Starch
Desi	Myles*	12.3	2.6	6.4	19.3	39.1
Kabuli	Bronic	7.7	2.9	5.8	21.1	37.5
	CDC Frontier	8.1	3.0	5.5	21.1	37.9
	CDC Leader	8.8	3.3	5.0	20.9	46.2
	CDC Orion	8.6	3.3	5.4	20.1	44.0
	CDC Palmer*	7.5	2.7	4.3	21.0	48.8
	Dylan*	4.2	3.4	5.5	20.1	41.8
	Hammond*	8.1	2.4	4.4	21.9	39.5
	Kasin*	7.3	2.8	4.0	25.1	34.6
	Nash	7.9	2.5	5.6	20.8	39.3
	ND Crown	8.7	3.4	5.1	20.0	44.6
	New Hope	9.2	3.8	5.6	21.0	44.6
	Pegasus*	6.9	2.4	4.3	21.6	38.2
	Royal	8.2	2.4	5.3	21.8	38.8
	Sawyer	7.4	3.0	5.7	22.3	41.3
	Sierra	7.3	3.0	5.5	21.7	38.9
	Vega*	7.5	2.7	5.2	18.4	40.2

* Value from only one sample.

Water hydration capacity of chickpeas ranged from 89 to 129%, with a mean of 108% (Table 30). The water hydration capacity of chickpeas from 2020 was essentially the same as the 5-year mean of 104%. Although, the water hydration capacity for the 2020 samples was higher than the five previous years except 2015. Differences in water hydration capacities among cultivars was observed. Among Kabuli chickpea, the Kasin cultivar had the highest water hydration capacity (129%) while Dylan had the lowest (102%) (Table 31). In contrast, the Myles (Desi chickpea) cultivar had a very low water hydration capacity. The **unhydrated seed percentage** was 0% for the Kabuli chickpeas while Desi chickpea had 80% unhydrated seed percentage. For Kabuli chickpea, the 0% unhydrated seeds matched the 5-year mean of 0% (Table 30). All of the cultivars except Myles had 0% mean unhydrated seed values (Table 31). The **swelling capacity** of chickpeas ranged from 121-188%, with a mean value of 145% (Table 30). The mean swelling capacity value of chickpea from 2020 was higher than the previous five years (2015-2019) and higher than the 5-year mean of 135%. The Kasin and Royal cultivars had the greatest mean swelling capacity while the New Hope cultivar had the lowest values among Kabuli chickpeas. The swelling capacity of CDC Frontier cultivar has been evaluated since 2014. The swelling capacity of 105% (2014), 116% (2016), 130% (2020), 134% (2018), 136% (2017, 2019) and 138% (2015) were observed over the 7-year period. The results show a consistent value over the last several years. In contrast to Kabuli chickpeas, the Desi chickpea tested had a low swelling capacity (Table 31).

Table 30. Physical parameters of chickpeas grown in the USA, 2015-2020.

Physical	Year							
	2020		2019	2018	2017	2016	2015	5-year
Parameter	Range	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean	Mean (SD)
Test Weight (lbs/bu)	55.1-65.3	61.6 (1.5)	61.0 (1.0)	62.0 (1.4)	61 (2)	61 (2)	60	61 (1)
1000 Seed Wt. (g)	262-569	417 (71)	444 (74)	410 (71)	421 (72)	410 (106)	404	426 (17)
Water Hydration Capacity (%)	89-129	108 (8)	102 (8)	102 (10)	104 (13)	105 (15)	108	104 (1)
Unhydrated Seeds (%)	0-80	0 (0)	0 (0)	0 (2)	0 (1)	1 (1)	0	0 (1)
Swelling Capacity (%)	121-188	145 (17)	138 (15)	130 (14)	129 (27)	141 (12)	136	135 (5)
Cooked Firmness (N/g)	14.5-31.1	19.6 (2.9)	20.7 (3.8)	27.9 (6.1)	26 (5)	22.0 (3.0)	19.7	23 (4)
% of Sample Retained on a 22/64 Sieve	1.0-96.5	55.6 (26.5)	64.2 (28.3)	*	*	*	*	nd
% of Sample Retained on a 20/64 Sieve	3.5-66.5	34.3 (18.6)	29.1 (20.8)	*	*	*	*	nd
% of Sample Retained on an 18/64 Sieve	0.0-85	9.7 (12.4)	6.1 (10.0)	*	*	*	*	nd
% of Sample Passed Through an 18/64 Sieve	0.0-3.5	0.4 (0.9)	0.6 (1.0)	*	*	*	*	nd

*data not reported; nd = not determined.

Table 31. Mean physical properties of chickpea cultivars grown in the USA, 2020.

Market Class	Cultivar	Test Weight (lbs/bu)	1000 Seed Wt. (g)	Water Hydration Capacity (%)	Unhydrated Seeds (%)	Swelling Capacity (%)	Cooked Firmness (N/g)	% of Sample Retained on a 22/64 Sieve	% of Sample Retained on a 20/64 Sieve	% of Sample Retained on an 18/64 Sieve	% of Sample Passed Through an 18/64 Sieve
Desi	Myles*	62.5	171	37	80	30	**	5.0	1.5	93.5	0.0
Kabuli	Bronic	63.0	335	107	0	154	17.5	13.6	62.3	21.5	2.6
	CDC Frontier	62.5	334	110	0	130	16.4	19.4	58.7	21.1	0.8
	CDC Leader	60.8	359	111	0	131	18.6	33.9	52.8	13.4	0.0
	CDC Orion	62.3	391	108	0	132	19.5	50.8	43.0	6.3	0.0
	CDC Palmer*	62.2	354	123	0	131	17.8	33.0	54.0	13.0	0.0
	Dylan*	58.6	561	102	0	160	21.3	92.0	5.5	2.5	0.0
	Hammond*	63.4	356	105	0	162	20.8	19.5	59.0	21.5	0.0
	Kasin*	65.3	262	126	0	182	19.5	1.0	14.0	85.0	0.0
	Nash	60.5	530	110	0	157	23.4	85.3	13.5	1.3	0.0
	ND Crown	61.2	384	111	0	133	18.2	65.9	30.9	3.2	0.0
	New Hope	61.6	394	108	0	129	17.6	53.8	41.2	5.0	0.0
	Pegasus*	60.2	535	115	0	174	21.1	87.0	10.0	3.0	0.0
	Royal	61.3	498	112	0	169	20.8	78.4	18.6	3.0	0.0
	Sawyer	63.1	361	112	0	140	19.0	28.8	49.8	21.3	0.0
	Sierra	60.8	470	103	0	149	21.0	77.5	17.9	4.1	0.5
	Vega*	61.1	472	104	0	169	23.5	72.5	22.5	5.0	0.0

* Value from only one sample; **firmness exceeded test maximum.

The **cooked firmness** of all chickpea ranged from 14.5 to 31.1 N/g, with a mean value of 19.6 N/g (Table 30). The mean firmness value for chickpea in 2020 matched the value from the chickpea grown in 2015 and was less than the 5-year mean value (23 N/g). This supports chickpea were less firm after cooking compared to chickpea from previous years. Among the cultivars, CDC Frontier had the lowest cooked firmness (16.4 N/g) while the Vega (23.5 N/g) and Nash (23.4 N/g) cultivars were the firmest (Table 31). The Desi chickpea remained sufficiently unhydrated that the firmness value exceeded the force maximum of the testing protocol. **Retention** of chickpea on a series of sieves was used to determine chickpea size. This was the second year of this test. The mean retentions of 55.6, 34.3, 9.7 and 0.4 % on the 22/64, 20/64, 18/ 64 and passed through the 18/64-inch sieves were observed in the 2020 chickpea, respectively (Table 30). The range of retention on the largest screen (22/64-inch sieve) was from 1 to 96.5%. The percentage of retention of chickpeas on the two largest screens (22/64 and 20/64-inch sieve) was approximately 90 and 93% for the chickpea harvested in 2020 and 2019, respectively. The highest percentage retention of the samples on the 22/64-inch sieve was observed for the Dylan (92%) while the lowest (1%) retention on the 22/64-inch sieve was observed in Kasin (Table 31).

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 32). **Color quality** indicated that the lightness (i.e., L*) of the chickpeas from 2020 was generally higher than previous years except 2015 (Table 32). In 2020, the a* value of 6.07 was most similar to the a* value of chickpea from 2019. The b* value for chickpeas from 2020 indicated a less yellow color compared to chickpea samples from 2015 to 2018 but more yellow than chickpea from 2019. The color of the chickpeas changed after the soaking process. Similar to peas and lentils, chickpea became lighter as evidenced by the higher L* values (Table 32) 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 2020 was similar to the color difference for samples from 2016 but higher than in chickpea from 2019 and lower than in chickpea from 2015, 2017-2018 (Table 32).

Among cultivars, Dylan had the highest L* value (64.26) while Kasin had the lowest (i.e., 57.60). The Dylan cultivar also had the highest L* value among chickpea cultivars in 2018 and 2019. Dylan had the lowest a* value among cultivars while CDC Leader (Kabuli) and Myles (Desi) had the highest a* values (Table 33). The highest yellowness value (i.e., b*) was observed in Bronic (Table 33). Visual observations support the color value differences as the Dylan cultivar appeared whiter in color than other cultivars. Most cultivars underwent an increase in lightness during soaking, as evidenced by the higher L* value of the soaked sample. However, Myles (Desi chickpea) had lower L* value after soaking, which may be the result the of the increased brown coloration that was observed after soaking. An increased yellowness was observed for all cultivars. The greatest color difference was observed in the Bronic cultivar (Table 39). The change in color observed in the CDC Frontier cultivar was likely due to the significant increase in lightness and yellowness during the soaking. The least change occurred in Dylan and Myles chickpeas.

Table 32. Color quality of chickpeas grown in the USA before and after soaking, 2015-2020.

Color Scale*	Mean (SD) Color Values											
	Before Soaking						After Soaking					
	2020	2019	2018	2017	2016	2015	2020	2019	2018	2017	2016	2015
L* (lightness)	60.47 (1.43)	55.69 (1.73)	53.45 (3.56)	55.01 (2.38)	53.01 (3.01)	66.86 (4.22)	61.39 (0.72)	56.16 (1.07)	56.68 (1.68)	57.27 (1.74)	55.57 (1.04)	70.33 (4.07)
a* (green-red)	6.07 (1.60)	5.17 (0.61)	9.06 (1.14)	8.55 (1.43)	9.09 (1.72)	7.83 (1.61)	6.41 (1.71)	5.21 (0.42)	11.35 (1.05)	10.85 (0.98)	11.44 (1.04)	6.97 (1.28)
b* (blue-yellow)	15.49 (1.37)	10.95 (0.80)	21.74 (1.70)	21.28 (1.99)	21.14 (2.07)	22.19 (2.55)	25.78 (1.72)	16.99 (6.41)	34.94 (2.20)	34.36 (2.41)	34.11 (2.31)	31.47 (7.70)
Color Difference	10.47 (1.79)	6.41 (1.13)	13.69 (1.96)	13.80 (1.78)	10.83 (6.02)	15.47 (3.10)						

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

Table 33. Mean color quality of chickpea cultivars grown in the USA, 2020.

Mean Color Values#								
Market Class	Cultivar	Before Soaking L*	Before Soaking a*	Before Soaking b*	After Soaking L*	After Soaking a*	After Soaking b*	Color Difference
Desi	Myles**	53.12	8.18	15.07	51.82	8.79	17.50	2.85
Kabuli	Bronic	58.67	5.19	17.57	62.03	4.72	29.32	12.30
	CDC Frontier	59.32	7.25	14.98	61.40	6.18	28.27	13.56
	CDC Leader	59.92	8.06	16.08	61.70	8.25	26.76	10.84
	CDC Orion	60.05	7.19	15.63	60.85	7.78	25.06	9.63
	CDC Palmer**	58.73	7.81	15.23	60.82	8.20	26.47	11.44
	Dylan**	64.26	1.70	16.67	60.27	2.77	22.73	7.36
	Hammond**	57.74	6.79	14.12	59.91	7.91	26.23	12.35
	Kasin**	57.60	7.36	16.25	61.84	7.53	27.34	11.88
	Nash	61.30	4.72	15.97	61.85	5.96	26.40	10.55
	ND Crown	60.76	7.00	15.37	60.96	7.64	25.94	10.66
	New Hope	62.21	5.23	14.58	61.70	7.19	25.04	10.13
	Pegasus**	60.58	6.47	14.51	61.70	7.70	25.27	10.88
	Royal	59.67	6.67	14.32	61.22	7.49	24.29	10.15
	Sawyer	60.72	6.63	15.02	62.07	6.72	24.31	9.43
	Sierra	61.53	4.65	15.52	61.54	4.81	25.16	9.73
	Vega**	61.50	6.26	15.16	61.34	6.95	24.82	9.69

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

Pasting properties (Tables 34-35)

Peak and hot paste viscosities of chickpeas grown in 2020 were similar to values for chickpea from 2019 and the 5-year mean value (Table 34). The cold paste viscosity of the 2020 chickpea crop was most similar to the chickpeas from 2015, 2017 and 2018. The peak time was slightly longer for samples from 2020 compared to other crop years except 2019. The pasting temperature was higher for the chickpeas from 2020 compared to the 5-year mean pasting temperature and the other harvest years. Peak, hot and cold paste viscosities of the Desi chickpea Myles cultivar had the lowest starch pasting viscosities among cultivars tested (Table 35). Among Kabuli chickpeas, Vega (124 RVU) and Hammond (126 RVU) had the lowest peak viscosity while CDC Palmer (171 RVU) had the highest peak viscosity. CDC Palmer (153 RVU) also had the highest hot paste viscosity while Sierra (119 RVU) had the lowest peak viscosity. The lowest and highest cold paste viscosities were observed in Dylan (232 RVU) and Hammond (162 RVU) and New Hope (163 RVU), respectively. Pasting temperature was lowest (76.7 °C) and highest (80.0 °C) for CDC Orion and Vega and Hammond cultivars, respectively.

Table 34. Starch characteristics of Kabuli chickpeas grown in the USA, 2015-2020.

Starch Characteristic	Year 2020 Range	2020 Mean (SD)	2019 Mean (SD)	2018 Mean (SD)	2017 Mean (SD)	2016 Mean (SD)	2015 Mean (SD)	5-year Mean (SD)
Peak Viscosity (RVU)	97-171	136 (16)	136 (18)	131 (15)	126 (15)	139 (23)	126 (15)	134 (7)
Hot Paste Viscosity (RVU)	93-153	128 (13)	131 (16)	125 (12)	124 (14)	134 (22)	124 (14)	130 (6)
Breakdown (RVU)	1-23	7 (5)	5 (4)	6 (6)	3 (2)	6 (4)	3 (2)	5 (1)
Cold Paste Viscosity (RVU)	116-232	186 (23)	198 (30)	187 (29)	185 (24)	214 (70)	185 (24)	198 (13)
Setback (RVU)	23-95	58 (15)	68 (18)	62 (20)	62 (13)	80 (43)	62 (13)	58 (24)
Peak Time (Minute)	4.53-7.00	6.12 (0.56)	6.33 (0.57)	6.06 (0.65)	6.00 (0)	6.04 (0.61)	6.00 (0)	6.09 (1)
Pasting Temperature (°C)	74.2-80.7	78.0 (1.4)	75.6 (1.6)	75.8 (1.9)	76 (2)	74.5 (1.3)	76 (2)	75.1 (1)

Table 35. Mean starch characteristics of chickpea cultivars grown in the USA, 2020.

Market Class	Cultivar	Peak Viscosity (RVU)	Hot Paste Viscosity (RVU)	Breakdown (RVU)	Cold Paste Viscosity (RVU)	Setback (RVU)	Peak Time (Min)	Pasting Temperature (°C)
Desi	Myles*	92	90	3	117	28	6.93	79.2
Kabuli	Bronic	131	126	5	186	60	6.45	78.8
	CDC Frontier	144	137	8	195	58	6.25	79.4
	CDC Leader	148	137	11	197	60	5.70	76.8
	CDC Orion	140	128	12	179	51	5.53	76.7
	CDC Palmer*	171	153	18	213	60	5.87	79.1
	Dylan*	143	141	2	232	91	7.00	78.5
	Hammond*	126	122	4	162	40	7.00	80.0
	Kasin*	143	134	9	169	36	6.07	79.2
	Nash	138	134	4	200	66	5.84	78.3
	ND Crown	155	143	12	208	65	5.83	77.2
	New Hope	130	124	6	163	39	6.13	78.0
	Pegasus*	130	129	1	206	76	6.60	78.3
	Royal	139	131	8	196	65	5.82	77.5
	Sawyer	138	130	8	198	68	5.87	77.5
	Sierra	123	119	4	173	55	6.58	78.6
	Vega*	124	123	1	204	81	6.07	76.7

* Value from only one sample.

Canning Quality

Canning quality was completed only on pea and chickpea. Lentils tend not to be canned unless they are a component of a soup. Therefore, the focus of this evaluation was 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

The mean **water hydration capacity** of canned peas was 214% for all peas (Table 36). This value was lower than the water hydration capacity of peas from the 2019 crop year. A difference in water hydration capacity between the green (198%) and yellow (226%) market classes was observed. Furthermore, Winter (217%) and Marrowfat (163%) were also canned and found to have similar or lower water hydration capacities. In comparison, water hydration capacities of peas in the soak test were 99 and 93% for green and yellow peas, respectively. Water hydration capacities ranged from 104 to 265% for all peas. In green peas, Hampton had the lowest mean water hydration capacity at 168% while Cruiser had the highest at 233%. However, several samples of Banner and Shamrock had water hydration capacities of 240 to 260%. In yellow cultivars, AAC Chrome had the lowest (172%) mean water hydration capacities while the DS Admiral cultivar had the highest (259%) value (Table 37). The results of the soak test did not directly translate into similar results in the canning water hydration in the context of an order.

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 150 to 260%, with a mean value of 205% (Table 36). The green pea cultivars CDC Greenwater and Ariel and Striker had the lowest (183%) and highest (217%) mean swelling capacities, respectively. However, individual samples of Hampton, Arcadia and Ginny 2 had swelling capacities between 240 and 260%. In yellow cultivars, AAC Carver had the lowest swelling capacity at 178% while Spider had the highest at 248%. Different cultivars accounted for the upper and lower swelling capacities between the canning and soak tests. The **canned firmness** values of peas were significantly lower than the cooked firmness values of soaked peas. This was anticipated since the canning involves higher temperatures followed by a room temperature equilibrium time of 3 weeks before firmness can be evaluated. The mean canned firmness value of all peas was 7.3 N/g (Table 36). This was higher than the 6 N/g observed in the 2019 canned peas. Furthermore, the mean cooked firmness for all peas was 24.9 N/g (Table 7). The Bluemoon (4.4 N/g) and Empire (4.5 N/g) cultivars had the least firmness among the green peas while Arcadia (9.9 N/g) was the firmest (Table 37). In yellow peas, Montech and LG Sunrise had the least (3.4 N/g) and greatest (12.4 N/g) firmness among yellow cultivars.

The color of the dry pea changed after the canning process. The color difference fell between 7.58 and 26.41, with a mean value of 12.99 for all peas, and 12.88 and 13.08 for the green and yellow market classes, respectively. The marrowfat pea had a color difference of 13.78. In this sample, a clear color change from a white appearance to a green appearance was noticeable. A slightly higher color difference was observed in canned peas compared to soaked peas. The lightness decreased during canning for both green and yellow market classes. In the soak test, only the green cultivars darkened upon soaking (Tables 10 and 11). The greatest color difference was observed in the Ariel (green) and Salamanca (yellow) cultivars after canning (Table 37) while the Shamrock (green) and Montech (yellow) cultivars had the lowest color difference. Shamrock also had the lowest color change in the 2019 canning evaluation.

Table 36. Mean physical and color parameters of canned dry pea grown in 2020.

				Mean Color Values*						
				Before Canning			After Canning			
Sample**	Hydration Capacity (%)	Swelling Capacity (%)	Canned Firmness (N/g)	L*	a*	b*	L*	a*	b*	Color Difference
All	214	205	7.3	61.35	2.09	12.42	54.41	2.19	22.46	12.99
Green	198	204	7.2	58.60	-1.87	9.46	51.62	-0.35	19.59	12.88
Yellow	226	206	7.4	63.47	4.99	14.57	56.46	4.14	24.49	13.08
Winter	217	211	7.3	56.18	-0.87	10.34	52.05	-1.24	21.53	12.07
Marrowfat	163	193	8.6	60.15	-0.51	10.83	52.73	-1.41	22.30	13.78

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.

Table 37. Mean physical and color parameters of canned dry pea cultivars grown in 2020.

Market Class	Cultivar	Hydration Capacity (%)	Swelling Capacity (%)	Canned Firmness (N/g)	Mean Color Value[#]						
					Before Canning			After Canning			
					L*	a*	b*	L*	a*	b*	Color Difference
Green	AAC Comfort**	198	216	7.7	61.80	-1.53	8.84	50.79	-0.36	17.27	13.92
	Aragorn	201	199	8.1	59.47	-2.44	9.00	51.05	-1.34	20.89	14.68
	Arcadia	174	205	9.9	60.23	-1.94	9.77	51.67	-0.11	18.16	12.29
	Ariel**	222	217	5.6	59.73	-2.33	9.16	51.54	-2.52	23.77	16.75
	Banner	203	195	6.3	57.12	-1.81	9.50	51.17	-1.16	20.68	12.97
	Bluemoon	230	189	4.4	57.65	-1.88	9.25	51.52	-0.20	19.67	12.81
	CDC Greenwater**	195	183	8.4	60.61	-1.92	8.24	49.82	0.40	17.61	13.80
	Cruiser	233	212	5.5	59.85	-1.63	8.79	51.81	-0.04	18.55	13.07
	Daytona	192	196	6.2	54.21	-0.97	9.32	53.15	1.06	18.71	13.15
	Empire	219	202	4.5	60.33	-0.97	8.38	52.60	0.84	19.48	13.04
	Fairway	202	192	6.6	57.07	-2.43	9.80	49.78	-1.73	20.12	12.98
	Ginny	193	209	7.2	59.09	-2.11	9.43	51.82	-1.60	20.29	13.34
	Greenwood	222	213	5.4	56.09	-2.12	8.90	51.00	-0.50	20.61	13.01
	Hampton	168	201	9.6	59.05	-1.96	10.34	50.89	0.31	18.39	11.82
	Majoret	225	214	5.9	58.99	-0.55	9.84	53.61	0.93	22.06	13.64
	Shamrock	214	210	6.4	54.76	-2.95	9.77	50.95	-0.14	19.96	11.39
	Striker**	214	217	5.6	60.79	-1.68	8.12	50.83	1.34	18.09	14.42
	Viper	181	195	6.4	61.98	-1.53	9.35	53.10	-2.75	22.37	15.87
Yellow	AAC Carver	225	178	5.7	63.63	5.39	14.20	57.65	4.75	24.72	12.37
	AAC Chrome**	172	193	10.8	65.03	4.87	14.23	55.36	5.79	23.53	13.45
	AAC Profit	205	201	5.6	63.98	5.25	14.72	57.82	4.33	25.07	12.49
	AC Agassiz**	183	197	10.5	66.76	5.04	14.47	55.81	5.58	22.90	13.83
	AC Earlystar	203	210	7.3	66.90	5.09	15.52	58.23	4.09	26.32	14.05
	Blaze	217	210	6.5	60.65	2.63	14.30	58.03	3.85	28.18	14.24
	Bridger**	219	227	4.9	65.00	5.17	15.82	59.01	4.46	25.64	11.52
	CDC Amarillo	189	210	6.7	63.51	5.39	14.87	56.91	3.84	24.91	12.32
	CDC Golden	210	218	5.9	63.78	4.73	14.77	58.34	3.96	28.36	14.83
	CDC Inca	196	205	8.6	61.81	5.14	14.61	56.12	3.81	23.80	12.36
	CDC Meadow**	178	220	10.4	64.37	5.28	15.95	58.09	3.48	29.43	14.98
	CDC Saffron**	204	203	6.6	65.74	4.95	14.03	55.12	5.14	20.51	12.49
	CDC Spectrum**	201	180	8.3	64.10	5.33	14.42	55.62	5.67	21.71	11.28
	Delta**	228	206	5.9	65.17	5.42	14.81	55.31	4.49	20.77	11.59
	DL Apollo**	206	216	7.7	64.89	5.34	15.97	55.95	5.53	23.25	11.62
	DS Admiral**	259	188	11.8	65.29	5.23	15.80	55.07	5.93	21.10	11.58
	Durwood	182	186	8.4	64.53	4.74	14.26	55.34	3.65	22.94	12.94
	Hyline	176	199	10.2	65.01	4.80	15.34	55.74	3.80	24.20	13.07
	Jetset**	182	180	10.4	64.58	5.35	14.29	55.08	6.03	22.64	12.74
	Korando	188	200	7.9	64.71	4.90	14.26	56.80	3.27	24.57	13.59
	LG Amigo**	211	207	7.6	65.12	5.91	14.23	55.69	5.40	22.78	12.74
	LG Sunrise**	181	225	12.4	64.33	4.98	15.00	55.20	5.71	23.73	12.66
	Montech**	191	221	3.4	62.80	5.59	16.33	58.02	2.07	23.48	9.29
	ND Dawn	220	234	7.4	61.34	5.35	14.64	56.82	4.37	23.78	12.58
	Nette 2010	194	205	8.8	62.15	4.69	14.62	55.70	4.66	21.79	9.91
	Pizzaz**	207	237	5.7	63.74	4.71	15.51	58.86	6.00	26.46	12.06
	Puris PP0667	204	207	5.3	62.94	5.56	16.02	57.88	4.91	25.26	11.00
	Salamanca	189	202	6.7	64.22	4.97	13.74	54.80	4.21	24.67	15.39
	Spider**	197	248	7.5	63.29	4.99	15.15	56.50	2.75	22.59	10.37
	Treasure	177	218	8.5	64.22	5.29	15.37	57.16	2.28	26.20	13.39
	Yellowstone**	216	214	9.8	65.78	5.42	14.48	53.88	2.26	19.40	13.85
Winter	Goldenwood**	183	206	10.8	58.78	2.03	14.57	54.89	3.73	20.81	7.58
	Vail	229	213	6.1	55.31	-1.84	8.93	51.10	-2.89	21.77	13.56
Marrowfat	145-22**	166	193	9.6	58.88	-0.59	10.68	53.14	-0.67	22.15	12.83
	90-7**	161	192	7.7	61.41	-0.43	10.98	52.32	-2.15	22.44	14.73

[#]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.

Chickpeas

The mean **water hydration capacity** of canned chickpea was 162% with a range from 141 to 188%. These values were comparable to the canned chickpeas from 2019. The water hydration capacity of canned chickpea was higher than that observed in the soak test (108%). The Dylan cultivar had the lowest water hydration capacity at 150% while Sawyer had the highest at 181% (Table 38). In the soak test, Dylan had the lowest water hydration capacity, which closely matched the outcome of the canning results. 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 150 to 205%, with a mean value of 177%. CDC Leader had the lowest mean swelling capacity at 164% while Vega had the highest at 200%. Desi chickpea swelled less than the Kabuli chickpeas as indicated by the low (159%) swelling capacity.

The **canned firmness** values of chickpeas were significantly lower than the cooked firmness values of soaked chickpeas. The mean canned firmness value of all chickpeas was 8.1 N/g. In comparison, the mean cooked firmness for all chickpeas was 19.6 N/g (Table 30). As expected, the canned chickpeas were less firm than the cooked chickpeas. Additionally, Desi chickpea had significantly higher (15.23) canned firmness than the Kabuli chickpea cultivars (Table 38). The Vega cultivar was the least firm while Sierra was the firmest (Table 38). The color of the chickpeas changed after the canning process. The color difference fell between 3.20 and 12.43, with a mean value of 8.35 for all chickpeas. A slightly higher color difference was observed in soaked (10.47) chickpeas compared to canned (8.35) chickpeas. The L* or lightness decreased during canning (Table 38). In contrast, the L* values of chickpeas generally increased in the soak test. The greatest color difference was observed in the Sierra cultivar after canning (Table 38). The substantial reduction in the L* value likely contributed the higher color difference value. The Kasin cultivar had the lowest color difference after canning. In general, hydration, color and firmness observations follow trends from previous evaluations.

Table 38. Mean physical and color parameters of canned chickpea cultivars grown in 2020.

					Mean Color Values[#]						
					Before Canning			After Canning			
	Cultivar**	Hydration Capacity (%)	Swelling Capacity (%)	Canned Firmness (N/g)	L*	a*	b*	L*	a*	b*	Color Difference
Desi	Myles**	160	159	15.23	53.39	8.29	15.25	49.87	5.94	10.70	6.21
Kabuli	Bronic	165	187	7.26	58.57	5.10	17.42	51.71	4.08	21.14	8.14
	CDC Frontier	161	175	7.95	59.52	7.30	15.08	53.32	5.04	19.54	8.05
	CDC Leader	165	164	8.05	59.88	8.00	16.00	54.18	6.49	19.79	7.24
	CDC Orion	160	170	8.28	59.56	7.23	15.65	54.21	5.91	19.34	7.10
	CDC Palmer**	168	171	8.35	58.50	7.80	15.18	53.95	6.94	19.35	6.23
	Dylan**	150	173	8.26	64.37	1.67	16.46	61.11	2.55	18.58	3.99
	Hammond**	162	166	7.08	57.68	6.78	13.96	54.83	6.35	21.95	8.49
	Kasin**	176	183	7.77	57.49	7.50	16.20	54.88	6.13	17.45	3.20
	Nash	159	173	8.15	61.48	4.70	16.11	52.23	4.62	17.76	9.41
	ND Crown	164	165	7.90	60.85	6.88	15.27	53.15	6.08	16.92	8.03
	New Hope	172	169	7.46	61.91	4.70	14.61	53.06	5.37	16.36	9.22
	Pegasus**	180	187	6.69	60.74	6.42	14.52	56.24	6.70	23.46	10.01
	Royal	166	186	7.49	59.89	6.61	14.23	55.87	5.99	21.44	8.39
	Sawyer	181	188	7.33	60.82	6.62	15.04	54.86	6.34	18.76	7.28
	Sierra	155	180	8.49	61.24	4.15	16.23	51.84	3.27	18.54	10.05
	Vega**	168	200	6.39	61.64	6.13	14.51	55.56	6.56	21.59	9.34

[#] 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. ** Value from only one sample.

Author

Dr. Clifford Hall, Professor, Pulse Quality, Dairy and Food Science, South Dakota State University, 106 Berg Agriculture Hall,

P.O. Box 2104, Brookings, SD, USA 56007.

Pulse Quality Technical Team

Serap Vatansever (Postdoctoral Associate), **Sushmita Karki** (Graduate Student)

Undergraduate lab researchers: **Jessica Christoffer**, **Dana Edelman**, **Jeffrey Lehman**, **Claire Olson**, **Emily Rogers**, **Noah Stavnes, Hannah Streich**

Funding Support

✓ Northern Pulse Growers Association
✓ U.S. Dry Pea and Lentil Council
✓ South Dakota State University Agriculture Experimental Station

Acknowledgements

The 2020 U.S. Pulse Quality team acknowledges support received from funding sources, and Andrea Schubloom for assistance creating the print version of the report. Please direct questions, comments, suggestions, or requests for copies of this report to Dr. Clifford Hall (clifford.hall@sdstate.edu) at South Dakota State University, Ms. Shannon Berndt (berndt@northernpulse.com) at Northern Pulse Growers Association, and Mr. Todd Scholz (tscholz@usapulses.org) at the USA Dry Pea and Lentil Council.

South Dakota State University
College of Agriculture, Food and Environmental Sciences

Dr. Clifford Hall
clifford.hall@sdstate.edu

USA Dry Pea & Lentil Council
https://www.usapulses.org/

Northern Pulse Growers Association
info@northernpulse.com; www.northernpulse.com