2018
U.S. Pulse Quality Survey

NDSU NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

Northern Pulse Growers Association

USA Dry Pea & Lentil Council

Contents

2018 Overview and Author's Comments

Summary Points

1. The 2018 pulse quality report represents the 11th variation of a pulse quality evaluation started by the Northern Crops Institute in 2008.
2. Data from approximately 236 samples received from major US pulse growing regions were evaluated.
3. Similar proximate composition to that of the 2016 and 2017 crop year was observed. Pasting properties mirrored the 5-year mean value. Other physical characteristics were similar to the values obtained in pulses from 2016.
4. Fat content of the pulses was evaluated for the second time in the survey history. Data supports the lowfat nature of peas and lentils. Chickpeas from 2018 tended to have slightly higher fat contents than 2017.
5. A canning quality evaluation was included for the second time in this report for pea and chickpea. Similar trends in results were observed between 2018 and 2017.

This report provides a summary of the 2018 pulse crop quality for dry pea, lentil, and chickpea cultivars grown commercially in the USA. In 2018, a total of approximately 236 pulse samples were collected from the major US pulse growing regions. The seeds evaluated included 105 dry pea, 52 lentil and 79 chickpea, which were acquired from pulses growers and industry representatives in pulse growing areas in Idaho, Minnesota, Montana, Nebraska, North Dakota, South Dakota and Washington. According to the USDA National Agricultural Statistics Service, pulse harvested acreage and estimated total production for 2018 was 2.3 million and 1.5 Million MT, respectively. Lentil production was up modestly from the 2017 production, although harvested acres were lower in 2018 compared to 2017. A significant gain in harvested chickpea acres was observed in 2018, which translated into increased chickpea production to 425,870 MT.

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, mineral, moisture, protein, and total starch content. For the second time, fat content was included in the proximate data. Water hydration capacity, percentage unhydrated seeds, swelling capacity, cooked firmness, test weight, 1000 seed weight, 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 indicates that the peas and lentils were similar to the 2017 crop year. Chickpea proximate composition was most similar to the chickpea harvested in 2014 and 2015 crop years. Similar to previous years, the 2018 pulse samples varied substantially in mineral composition from other years. The difference might be related to the more diverse pool of samples from different growing locations. The pulse samples evaluated

in 2018 came from the most diverse growing regions since the survey was started. In general, peas and lentils from 2018 had either similar or lower moisture contents compared pulses from other crop years while chickpeas tended to have similar moisture content to chickpea from 2015 and 20167, and had moisture contents slightly higher to the 5-year mean moisture values. The total starch contents were lower than the five-year average. However, within pulse categories some of the parameters were comparable to the 5-year mean value. The fat contents of the pulses evaluated were within ranges reported in the literature. However, the fat contents of all pulses from 2018 were higher than the fat contents of pulses from 2017. The yellow and green dry pea composition was nearly identical to each other. The yellow peas tended to have lower protein, but higher starch compositions compared to the green peas. Lentils from 2018 had the higher protein composition compared to lentils from previous years. Differences in proximate composition were observed between the three lentil market classes. The green and Spanish brown had similar protein and starch contents while the red lentils had higher protein but less starch than the other two market classes. Both protein and starch contents were higher in chickpeas from 2018 compared to chickpea from 2016 and 2017. Similar to results reported previously, the pulses grown in 2018 are an excellent source of a wide range of mineral including iron (Fe), zinc (Zn), magnesium (Mg) and selenium (Se). The 2018 pulses provide in excess of 10% of the RDA for these minerals. The mineral concentrations tended to be higher in peas from 2018 compared to other years. However, potassium and phosphorus were significantly higher in 2018 compared to previous years with a few exceptions. Regardless of market class, dry peas from 2018 had lower magnesium levels compared to 2015 and 2016, but higher than the peas from 2013, 2014 and 2017. The calcium content of the peas from 2018 were lower than previous. The other minerals fell within the range of the previous crop years. Similar trends in mineral composition of lentils were observed with only a few exceptions. Differences in mineral composition between lentil market classes were minimal. The major minerals composition in chickpeas from 2018 were similar to those from the 2015 through 2017 crop years. However, potassium and selenium concentration were higher in chickpea from 2018 compared to chickpea from other years.

The physical parameters such as water hydration capacity, test weight, and color analysis of the 2018 had varying result compared to previous pulse crops. Overall, the test weight of dry peas, lentils and chickpeas were approximately that of the 5-year average. The 1000 seed weight was slightly lower for peas, lentils and chickpeas compared to the 5-year mean. The water hydration capacities of the pulses were similar to the 5-year mean. The physical parameters of the 2018 lentils were most comparable to the lentils from 2017 and in a few of the parameters (e.g., swelling capacity) were comparable to the lentils from 2016. Swelling capacity of chickpea from 2018 was comparable to chickpea from 2015 and 2017.

The color of the peas was comparable to the peas from 2016 and 2017. The lightness (L*) color quality and color difference values of dry peas from 2018 were most like the peas from 2017, although the green peas were darker and greener. The color tended to be darker in lentils from the green and Spanish brown market classes compared to lentils from previous crop years while red lentils tended to be slightly lighter in color. The 2018 chickpea crop had slightly less lightness values compared to previous crop years. However, the redness and yellowness values were similar to chickpeas grown in 2017, which tended to be higher than chickpeas from 2013.

The starch pasting properties closely matched those of the peas from 2015 and 2017. The paste that resulted from the 2018 pea flour was less viscous than the paste from the pea flour from the 2016 crop year. The peas from the yellow market class had viscosity properties that were similar to the yellow peas from 2014, 2015 and 2017 while the pasting characteristics of green peas from 2018 closely aligned with pea from 2017. The pasting properties of the lentil flour from 2018 were similar to the pasting properties of lentils from 2017. Differences in pasting properties were found between lentil cultivars. The pasting characteristics of the green market class exceeded the 5-year mean viscosity values while the red market class had pasting values just slightly greater than the 5-year mean. The viscosity values of Spanish Brown lentils were less in 2018 compared to lentils from 2017. Pasting properties of chickpea from 2018 mirrored the pasting properties of the chickpea from 2015 and 2017.

The canning evaluation was completed for a second time since the survey inception. Overall, the canning quality of pea and chickpea from 2018 was comparable to the quality obtained during canning in 2017. Water hydration capacity, swelling capacity, canned firmness and color difference between dried and canned peas and chickpeas were evaluated. Water hydration and swelling capacities increased substantially more in peas than in chickpea, which supported observations in 2017. Peas also had very soft texture as supported by the low canned firmness values. Chickpea had higher canned firmness values than peas, but were less firm than cooked chickpea.

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.

I would like to thank the USA pulse producers for their support of this survey.

Sincerely,

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Pulse Production

The Northern Plains region and Pacific Northwest are the largest pulse producing area within the USA. US pulse harvested acreage in 2018 was 2,245,700 (USDA 2018; Table 1), which was approximately 300 thousand less acres than in 2017. Total US pulse production (Metric Tons (MT) in 2018 is estimated to be 1,460,378, which is up from the 1,304,132 produced in 2017, but down from the high of 1,927,285 from 2016. The drought conditions affecting the pulse growing regions likely contributed to the lower production compared to 2016. Pulse production was higher than the 1,113,245 MT and 1,061,732 MT produced in 2015 and 2014, respectively. Although more acres were planted in 2017.

The UDSA (2018) estimated that the dry pea acreage was 836,400, which was down from the 1,154,500 harvested acres in 2017 and 1,334,800 in 2016 (Table 1). Pea production (635,936 MT) was comparable to the 2017 production (648,251 MT) despite having less harvested acres (Table1). Lentil acreage was 758,000 compared to 957,000 in 2017, 917,000 acres in 2016, 476,000 in 2015 and 265,703 in 2014 (USDA; Table 1). Lentil production (398,572 MT) in 2018 was higher than the 380,905 MT in 2017 but lower than the 564,087 MT in 2016.

Chickpea harvested acres (651,300) in 2018 was higher than the 476,300 acres in 2017 and significantly higher than the 277,500 in 2016, 203,100 in 2015, and 202,253 acres in 2014 (USDA 2018). Production was estimated at 425,870 MT in 2018, which was higher than the 234 thousand MT in 2017 and was substantially higher than the 135,016 MT in 2016, 98,817 MT in 2015, and 127,386 MT in 2014.

The increased production of the pulses supports increased yields per acres. In 2018, the mean pea yield was 1,698 lb/acre while in 2017 the yield was1,372 lb/acre. Lentil yields in 2018 were 1,149 lb/acre while in 2017 the yield was 877 lb/acre. Chcikpea yields were 1,437 and 1,106 lb/acre in 2018 and 2017, respectively. The drier growing conditions in 2017 likely contributed to lower yields in 2017.

Table 1. United States pulses acreage and production summary for 2014-2018.

	2018		2017		2016		2015		2014	
Crop	Acreage*	Production**	Acreage	Production**	Acreage	Production**	Acreage	Production**	Acreage	Production**
Dry Peas	836,400	635,936	1,108,900	648,251	1,334,800	1,228,282	1,083,500	738,203	924,278	783,098
Lentil	758,000	398,572	957,000	380,905	917,000	564,087	476,000	276,225	265,703	151,248
Chickpea	651,300	425,870	476,300	238,975	277,500	135,016	203,100	98,817	202,253	127,386
Total	**2,245,700**	**1,460,378**	**2,542,200**	**1,304,132**	**2,529,300**	**1,927,385**	**1,762,600**	**1,113,245**	**1,392,234**	**1,061,732**

**Acreage = Acres Harvested - USDA NASS (2018); **Production = Metric Tons - USDA NASS (2018).

Laboratory Methods Used to Measure Pulse Quality

Where applicable, standard methods were followed for the determination of each pulse quality attribute in 2017 (Table 2). The fat (i.e. lipid) content and canning methods were added in 2017. These methods were again evaluated in 2018. For most other analyses, data is provided on data collected between 2013 and 2018. The data is report as a range, mean and standard deviation (SD) for the 2018 harvest year while preceding years were provided as a means plus SD. Data on cultivars was reported only for the 2018 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 contains 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 represent 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 2018 pulse quality survey.

Quality Attribute	Method	Remarks
1. Moisture (%)	AACC International method 44-15A	Indicator of post-harvest stability, milling yield and general processing requirements.
2. Protein (%)	AACC International method 46-30	Indicator of nutritional quality and amount of protein available for recovery.
3. Ash (%)	AACC International method 08-01	Indicator of total non-specific mineral content.
4. Total starch (%)	AACC International 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. Minerals	Thavarajah et al., 2008, 2009	Indicator of nutritional quality as related to specific minerals.
7. Test weight (lb/bu)	AACC International method 55-10	Indicator of sample density, size, and shape.
8. 1000 seed weight (g)	100-kernel sample weight times 10	Indicator of grain size and milling yield.
9. Water hydration capacity (%)	AACC International method 56-35.01	Indicator of cooking and canning behavior.
10. Unhydrated seed (%)	AACC International method 56-35.01	Indicator of cooking and canning behavior and the amount of seed 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-310 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): ΔE*ab= [(ΔL*)2 + (Δa*)2 + (Δb*)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 International 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 International 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.	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 105 dry pea samples were collected from Idaho, Minnesota, Montana, Nebraska, North Dakota, Oregon, South Dakota and Washington from July to November 2018. Growing location, number of samples, market class, and genotype details of these dry pea samples were recorded (Table 3). The majority of the peas were obtained from Montana and North Dakota. Green peas accounted for 39 of the samples collected, where Banner (8), Ginny (5), Arcadia (4) and Shamrock (4) accounted for the majority of the green peas evaluated. The remaining samples were a mix of various cultivars (Table 3). Yellow peas accounted for 66 of the pea samples collected, where AC Earlystar (8), AAC Craver (6), Agassiz (5), and Nette (4) 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). A significant number (31) were not identified by cultivar name and were listed as unknown in the data.

Table 3. Description of dry pea samples used in the 2018 pulse quality survey.

State	No. of samples	Market class	Cultivars	
Idaho	8	Green	Banner	Icicle
		Yellow	Ewald	
Minnesota	2	Green	Unknown	
		Yellow	Unknown	
Montana	27	Green	Aragorn Banner	Ginny Greenwood
		Yellow	AC Earlystar CDC Meadow Montech 4152	Bridger Korando Montech 4193
Nebraska	1	Yellow	AC Earlystar	
North Dakota	57	Green	Arcadia Ginny Shamrock	CDC Greenwater Majorette
		Yellow	AAC Carver Admiral Bridger CDC Leroy Gunner Nette Spider	AC Earlystar Agassiz CDC Amarillo CDC Meadow Mystique Salamanca
Oregon	1	Green	Ariel	
South Dakota	4	Yellow	AAC Carver	AC Earlystar
Washington	5	Green	Ariel Hampton	Ginny Pro 7123
		Yellow	Universal	

Proximate composition of dry pea (Tables 4-6)

Moisture

The moisture content of dry pea ranged from 7.0-13.3% in 2018 (Table 4). The mean moisture content of all 105 pea samples was 9.6%, which is the same as the 5-year mean of 9.6%. Dry peas grown in 2018 had moisture contents similar to pea samples from the 2017 harvest year. 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.

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 9.0 and 9.7%, respectively, were approximately the same as the 5-year mean values of 9 and 10%,respectively. The highest moisture contents were observed in the CDC Greenwater cultivar (i.e. green pea) and the Salamanca cultivar in the yellow market class (Table 6). However, most of the green peas had moisture contents between 8.5 and 10% range while yellow peas had moisture contents between 10.3 and 11%. However, and all pulses remained under the maximum moisture of 14%, which is necessary for storing pulses.

Table 4. Proximate composition of dry pea grown in the USA, 2013-2018.

Proximate Composition (%)*	2018		Mean (SD)					5-year Mean (SD)
	Range	Mean (SD)	2017	2016	2015	2014	2013	
Moisture	7.4-13.0	9.6 (1.0)	9.5 (1.1)	10.1 (1.0)	10.9 (1.5)	11.3 (1.3)	6 (3.0)	9.6 (2.1)
Ash	1.9-3.2	2.5 (0.2)	2.5 (0.2)	2.5 (0.2)	2.5 (0.2)	2.3 (0.2)	2.5 (0.1)	2.5 (0.1)
Fat	1.2-5.5	2.8 (0.8)	2.1 (0.7)	**	**	**	**	nd
Protein	17.8-26.1	21.4 (1.6)	21.5 (1.8)	20.8 (1.6)	20.3 (1.7)	22.5 (1.3)	25 (3.5)	22.2 (1.9)
Total Starch	35.9-46.7	42.5 (1.9)	41.9 (2.0)	42.8 (3.1)	41.7 (4.0)	43.6 (2.1)	52 (6.5)	44.6 (4.2)

*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, 2013-2018.

Proximate Composition (%)*	Mean (SD) of green pea						5-year Mean (SD)
	2018	2017	2016	2015	2014	2013	
Moisture	9.2 (1.1)	9.0 (1.1)	9.6 (1)	10 (1)	11 (1)	5 (3)	8.9 (2.3)
Ash	2.5 (0.2)	2.5 (0.2)	2.4 (0.2)	2.5 (0.2)	2.3 (0.2)	2.5 (0.1)	2.4 (0.1)
Fat	2.9 (0.8)	2.1 (0.7)	**	**	**	**	nd
Protein	22.0 (1.8)	21.6 (2.0)	21.0 (2)	21 (2)	23 (1)	23 (3)	22.0 (1.0)
Total Starch	42.3 (1.6)	41.4 (2.1)	42.1 (3)	41 (3)	44 (2)	52 (7)	44.1 (4.6)
Starch Characteristics	**Mean (SD) of yellow pea**						**5-year Mean (SD)**
	2018	**2017**	**2016**	**2015**	**2014**	**2013**	
Moisture	9.9 (0.9)	9.8 (0.9)	10.5 (1)	11.5 (1)	12 (1)	7 (3)	10.1 (1.89)
Ash	2.5 (0.2)	2.5 (0.2)	2.6 (0.2)	2.4 (0.2)	2.4 (0.1)	2.4 (0.1)	2.5 (0.1)
Fat	2.7 (0.8)	2.2 (0.8)	**	**	**	**	nd
Protein	21.1 (1.5)	21.4 (1.7)	20.6 (2)	19.9 (2)	22 (1)	23 (4)	21.4 (1.2)
Total Starch	42.6 (2.0)	42.2 (1.9)	43.3 (3)	41.2 (5)	43 (1)	52 (6)	44.3 (4.4)

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

Table 6. Mean proximate composition of dry pea cultivars grown in the USA in 2018.

Market Class	Cultivar	Concentration (%)				
		Moisture	Ash	Fat	Protein	Starch
Green	Arcadia	9.7	2.6	2.6	20.7	42.9
	Ariel	7.7	2.4	2.4	21.5	45.5
	Banner	8.5	2.5	3.1	21.6	41.7
	CDC Greenwater*	9.9	2.5	2.2	22.4	40.4
	Ginny	9.7	2.4	3.2	22.2	43.0
	Hampton*	8.0	2.4	2.9	24.3	41.9
	Icicle*	8.4	2.5	3.7	21.3	41.4
	Majorette*	8.8	2.6	4.0	23.6	43.3
	PRO 7123	8.1	2.5	3.3	23.5	40.9
	Shamrock	9.6	2.6	2.3	24.0	41.4
	Unknown	9.7	2.6	2.8	21.3	42.4
Yellow	AAC Carver	10.5	2.5	2.0	20.0	43.0
	AC Earlystar	9.8	2.5	2.0	20.9	41.8
	Agassiz	10.3	2.6	2.6	20.9	43.0
	Bridger	10.4	2.6	2.3	20.0	41.4
	CDC Amarillo	10.7	2.6	1.8	20.5	41.4
	CDC Leroy*	9.1	3.2	1.4	25.8	41.4
	CDC Meadow	9.2	2.4	2.2	22.3	43.0
	DS Admiral*	11.3	2.3	3.0	19.9	43.5
	Ewald*	8.5	2.7	2.3	24.7	41.9
	Gunner*	10.9	2.4	4.4	20.9	45.9
	Korando	9.8	2.5	2.4	22.9	39.5
	Montech 4152*	9.0	2.6	3.2	19.3	35.9
	Montech 4193	8.8	2.8	3.2	22.0	42.0
	Mystique	10.5	2.4	2.2	19.9	42.9
	Nette	10.4	2.5	2.6	20.9	42.9
	Salamanca*	11.9	2.5	2.1	19.5	41.4
	Spider*	11.0	2.5	3.2	21.8	42.0
	Universal*	7.9	2.4	2.6	22.7	41.8
	Unknown	9.4	2.6	3.4	21.3	43.6

*Only one sample of cultivar tested

Ash

Ash content of dry pea ranged from 1.9-3.2%, with a mean of 2.5%. The mean ash content of dry peas grown in 2018 was identical to the 5-year mean (Table 4). Only the peas from the 2014 harvest year had a different ash content. Ash content is a general indicator of minerals present. The ash contents of yellow and green market classes were both 2.5% (Table 5). The green and yellow pea ash contents were similar to their respective 5-year mean value of 2.4 and 2.5%. Some variability in ash content was observed among cultivars (Table 6). However, this variability was greater in the yellow market class. The ash ranged from 2.3% (DS Admiral) to 3.2% (CDC Leroy). In 2017, DS Admiral also had the lowest (2.2%) ash content among yellow peas.

Fat (Lipid)

Fat content of dry pea ranged from 1.2 to 5.5%, with a mean of 2.8%. The mean fat content in 2017 was 2.1%. However, the upper values observed in 2018 were slightly higher than published reports for total oil (i.e. fat), being in the range of 1 to 4 %. The fat contents of the green and yellow market classes were approximately the same (Table 5). The Majorette (green) and Gunner (yellow) had the highest fat contents in their respective market classes (Table 6). In contrast, CDC Greenwater (green) and DS Admiral (yellow) had the lowest fat contents among their respective market classes.

Protein

Protein content of dry pea ranged from 17.8 to 26.1% with a mean of 21.4%. The mean protein content was comparable to the peas from the 2017 crop year and slightly higher than peas from 2015 and 2016, but lower than 2013 and 2014 crop years. The mean protein content of dry peas grown in 2018 was lower than the 5-year mean of 22.2%. The lower protein might be an artifact of the dry conditions observed during the 2018 growing season in some location. Furthermore, a greater number of samples were evaluated in 2018 compared to 2014 (i.e. 60 samples).

The protein contents of the green and yellow market classes were approximately the same (Table 5). The green peas from 2018 had lower protein content compared to 5-year mean value (21% vs. 22%), but was similar to protein contents in peas from 2017. Yellow peas had a mean protein content (21.1%), which was similar to the 5-year mean value (21.4%). Hampton (green, 24.3%) and CDC Leroy (yellow, 25.8%) cultivars had the highest protein contents in their respective market classes (Table 6). In contrast, Arcadia (green) and Salamanca (yellow) had the lowest protein contents among their respective market classes.

Total starch

Total starch content of dry pea ranged from 39.5 to 46.7% with a mean of 42.5%. The mean total starch content of dry peas grown in 2018 was comparable to dry peas from the 2016 harvest year (i.e. 42.8%), but lower than the 5-year mean of 44.6%.

The starch contents of the green and yellow market classes were both approximately 42.3 and 42.6%, respectively (Table 5). Green peas had a mean starch content (42.3%) that was lower than the 5-year mean value of 44.1%.

Although the 5-year mean value for the yellow peas was higher (44.1%) than the mean starch content (42.6%), the mean starch content of yellow peas harvested in 2018 was higher than the yellow peas obtained from the 2017 and 2015 harvest years. Ariel had the highest (45.5%) starch content among the green peas while Gunner had the highest starch content (45.9%) in yellow peas. CDC Greenwater (40.4%) and Montech 4152 (35.9%) had the lowest starch contents in green and yellow peas, respectively (Table 6).

Mineral composition of dry pea (Tables 7-8)

Mineral composition varies the most among the proximate chemical components tested in 2018. The mean calcium content for all pea samples was 575 mg/kg with a range in values of 382 to 935 mg/kg. Iron content ranged from 31 to 70 mg/kg with a mean value of 47 mg/kg. Selenium mean content was 224 mg/kg with a range in values of 162 to 331 µg/kg. The variability in mineral content is further illustrated by the range in potassium (5815 to 9789 mg/kg) and phosphorus (2160 to 6396 mg/kg) contents. The variability in minerals likely relates to the soil in which the pulse is grown. Samples evaluated were from different growing regions and that may have impacted mineral composition. Potassium and phosphorus account for the highest amounts of minerals in the

Table 7. Mineral concentrations of dry pea grown in the USA, 2013-2018.

Micronutrient (mg/kg)	Mean (SD) of green pea						5-year Mean
	2018	2017	2016	2015	2014	2013	
Calcium	554 (81)	597 (98)	552 (82)	534 (91)	554 (106)	333 (169)	514 (104)
Copper	6 (1)	7 (1)	6 (1)	5 (1)	6 (1)	6 (2)	6 (1)
Iron	47 (6)	51 (7)	45 (6)	44 (7)	42 (6)	41 (14)	45 (4)
Magnesium	1080 (44)	1059 (47)	1224 (106)	1280 (82)	813 (41)	689 (242)	1013 (256)
Manganese	12 (3)	10 (2)	10 (2)	9 (1)	9(2)	11 (4)	10 (1)
Phosphorus	4173(731)	2456 (251)	3792 (810)	3179 (404)	2583 (326)	2902 (1190)	2982 (533)
Potassium	7519 (486)	6946 (542)	5781 (448)	6709 (662)	8801 (715)	7529 (1801)	7153 (1116)
Zinc	26 (5)	30 (6)	24 (4)	24 (4)	32 (7)	38 (6)	30 (6)
Selenium (µg/kg)	231 (40)	206 (62)	176 (29)	151 (49)	369 (65)	300 (300)	240 (91)

Micronutrient (mg/kg)	Mean (SD) of yellow pea						5-year Mean (SD)
	2018	2017	2016	2015	2014	2013	
Calcium	588 (108)	630 (90)	593 (87)	571 (114)	599 (119)	494 (173)	577 (51)
Copper	6 (1)	8 (2)	6 (1)	5 (1)	6 (1)	5 (2)	6 (1)
Iron	46 (8)	50 (7)	45 (7)	38 (5)	42 (7)	36 (13)	42 (6)
Magnesium	1092 (52)	1116 (60)	1351 (88)	1319 (80)	817 (111)	728 (182)	1066 (285)
Manganese	11 (2)	10 (1)	11 (2)	8 (2)	10 (2)	11 (3)	10 (1)
Phosphorus	3639 (853)	2424 (273)	4695 (981)	2912 (307)	2522 (395)	2223 (869)	2955 (1004)
Potassium	7478 (651)	6918 (550)	6441 (508)	6168 (594)	8056 (2271)	6335 (1477)	6784 (764)
Zinc	25 (6)	31 (4)	24 (4)	21 (3)	32 (7)	29 (8)	27 (5)
Selenium (µg/kg)	220 (41)	216 (38)	197 (31)	200 (47)	365 (125)	500 (300)	296 (134)

*data not reported; nd= not determined

pea samples regardless of market class (Table 7). The potassium content of green peas from 2018 was higher than the potassium in green peas from 2015 and 2017 crop years, but lower than the 2014 crop year. The yellow peas from 2018 had mean potassium levels higher than previous crop years except 2014. In general, phosphorus content in green and yellow peas was higher than samples from the fiv e previous years. Only yellow peas from 2016 had higher phosphorus. Calcium was lower in peas grown in 2018 compared to peas from 2017, but comparable to the previous years for both green and yellow peas (Table 7). Magnesium composition in both green and yellow peas from 2018 was lower in pea samples from 2015 and 2016, but higher than the magnesium contents in peas from 2012-2013 harvest years. Green peas also had magnesium levels higher than those determined in 2017. The trace mineral (copper, iron, manganese and zinc) contents of peas harvested in 2018 tended to be lower than the values from the 2017 peas, but higher than those of the other previous harvest years (Table 7).

The mineral content of dry pea cultivars varied significantly for some of the individual minerals (Table 8). The calcium content of green peas ranged from 464 mg/kg in CDC Greenwater to 768 mg/ kg in PRO 7123. The calcium content varied from 457 mg/kg to 768 mg/kg in Montech 4193 and Bridger yellow pea cultivars, respectively. Potassium content in Ariel and CDC Leroy were highest (7864 and 9474 mg/kg) among the green and yellow pea cultivars, respectively, while Ginny and Gunner had the lowest (7006 and 6778 mg/kg) potassium contents among green and yellow pea cultivars, respectively. Similar variability existed in the trace minerals, but to a lesser degree (Table 8). The emphasis on soil mineral composition is important as soil mineral content often is indicative of mineral composition in the plant. Therefore, the data was not surprising in that the same cultivars from 2017 did not have either the highest or lowest mineral composition.

Table 8. Mean mineral concentrations of dry pea cultivars grown in the USA in 2018.

Market Class	Cultivar	Concentration (mg/kg)*								(µg/kg)
		Ca	Cu	Fe	K	Mg	Mn	P	Zn	Se
Green	Arcadia	574	5	44	7765	1107	13	3850	23	213
	Ariel	528	5	46	7864	1103	11	4449	24	204
	Banner	545	6	49	7715	1098	10	4595	28	208
	CDC Greenwater*	464	5	40	7699	1081	10	3581	19	225
	Ginny	616	5	46	7006	1041	12	3824	25	222
	Hampton*	725	7	59	7672	1090	12	4743	34	205
	Icicle*	518	6	58	7746	1075	13	4521	31	198
	Majorette*	454	6	46	7206	1086	15	3709	30	293
	PRO 7123	734	5	53	7701	1108	12	4657	28	230
	Shamrock	518	6	48	7692	1052	12	4711	30	289
	Unknown	512	6	44	7319	1074	11	3784	23	242
Yellow	AAC Carver	659	5	41	7309	1090	11	3146	23	196
	AC Earlystar	587	5	42	7220	1070	11	3193	24	218
	Agassiz	542	5	49	7950	1100	10	3548	24	193
	Bridger	768	6	45	7682	1103	9	4335	25	225
	CDC Amarillo	611	6	44	7173	1097	11	3287	24	179
	CDC Leroy*	551	8	70	9474	1232	13	6396	45	217
	CDC Meadow	472	7	55	7330	1054	15	2646	28	216
	DS Admiral*	617	5	40	7392	1130	14	4450	23	197
	Ewald*	619	7	58	8410	1190	10	4765	45	171
	Gunner*	585	5	37	6778	1138	10	3544	20	232
	Korando	747	5	52	7084	1085	10	3731	26	221
	Montech 4152*	579	6	47	7768	1095	11	4360	31	262
	Montech 4193	457	6	35	7802	1052	9	5136	24	269
	Mystique	643	5	43	7455	1092	10	2759	16	199
	Nette	666	6	46	7724	1134	12	3760	26	189
	Salamanca*	738	5	36	7371	1076	11	2855	21	205
	Spider*	504	6	43	6955	1103	11	4054	23	229
	Universal*	548	6	56	7175	1085	13	4278	25	208
	Unknown	536	6	48	7442	1083	12	3661	26	246

*mineral key: calcium (Ca), copper (Cu), iron (Fe), potassium (K), magnesium (Mg), manganese (Mn), Phosphorus (P), Zinc (Zn) and selenium (Se);
**Only one sample of cultivar tested

Physical parameters of dry pea (Tables 9-13)

Test weight ranged from 59 to 66 lbs/bu with a mean of 63.5 lbs/bu. This mean value was the approximately same as the 5-year mean of 63 lbs/bu (Table 9). The test weight for all pea samples harvested in 2018 was comparable to those from 2013 to 2017. The test weights of peas in the green and yellow market classes were 63 and 64 lb/bu, respectively (Table 10). The test weight of individual cultivars was comparable to one another and fell within the range of 62 to 65 lb/bu (Table 11). Salamanca had the highest (66 lb/bu) while the lowest was 62 lb/bu for the Hampton, Icicle, PRO 7123 Aggassiz, DS Admiral and Universal Cultivars.

The range and mean **1000 seed weight** of dry peas grown in 2018 were 115-283 g and 211 g, respectively (Table 9). The mean value (211g) was lower than the mean 1000 seed weight of peas evaluated in the 2013 to 2016, but was comparable to the 1000 seed weight observed in the 2017 harvest year. Peas of the green market class had a mean 1000 seed weight of 192 g, which is lower than the 5-year mean value of 208 g (Table 10). The green peas from 2017 harvest year had lower 1000 seed weight compared to peas from 2018. Peas of the yellow market class had a mean 1000 seed weight of 222 g, which is the same as the 5-year mean 100 seed weight (Table 10). The individual cultivars (Table 11) varied extensively in 1000 seed weight, where the cultivars in the green market class varied (115 to 260 g) slightly less than cultivars in the yellow market class (131 to 282 g). This was a similar trend for the peas harvested in 2017. Icicle (115 g) and CDC Leroy (131 g) and CDC Greenwater (260 g) and Salamanca (283 g) had the lowest and highest 1000 seed weight in the green and yellow market class, respectively (Table 11).

The **water absorption** or hydration properties of peas is important for understanding how peas will hydrate and increase in size and weight. We can

Table 9. Physical parameters of dry pea grown in the USA, 2013-2018.

Physical Parameter	Year							
	2018		2017	2016	2015	2014	2013	5-year
	Range	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Test Weight (lb/bu)	59-66	63.5 (1)	63 (2)	63 (4)	64 (2)	63 (2)	64 (2)	63 (0.5)
1000 Seed Wt (g)	115-283	211 (33)	204 (32)	224 (29)	215 (36)	216 (27)	222 (31)	216 (7)
Water Hydration Capacity (%)	80-150	103 (8)	104 (14)	97 (6)	102 (16)	102 (5)	98 (13)	101 (3)
Unhydrated Seeds (%)	0-11	1 (2)	2 (2)	2 (3)	2 (2)	2 (1)	8 (9)	3 (2)
Swelling Capacity (%)	74-174	147 (14)	148 (10)	137 (16)	152 (17)	152 (8)	*	nd
Cooked Firmness (N/g)	12.2-33.9	21.0 (5)	24 (6)	23 (5)	21 (6)	*	*	nd

*data not reported; nd = not determined

Table 10. Physical parameters of different market classes of dry pea grown in the USA, 2013-2018.

Physical Parameter	Mean (SD) of green pea						5-year
	2018	2017	2016	2015	2014	2013	Mean (SD)
Test Weight (lb/bu)	63 (1)	63 (2)	63 (6)	63 (2)	63 (2)	63 (2)	63 (0)
1000 Seed Wt (g)	192 (28)	190 (28)	213 (29)	207 (43)	219 (21)	212 (29)	208 (11)
Water Hydration Capacity (%)	106 (8)	107 (20)	100 (6)	114 (11)	100 (6)	102 (14)	105 (6)
Unhydrated Seeds (%)	0 (1)	2 (2)	1 (1)	2 (2)	1.0 (1)	8 (9)	3 (3)
Swelling Capacity (%)	149 (12)	146 (11)	140 (16)	142 (23)	150 (13)	*	nd
Cooked Firmness (N/g)	19.8 (5)	22 (5)	23 (5)	17 (5)	*	*	nd

Physical Parameter	Mean (SD) of yellow pea						5-year
	2018	2017	2016	2015	2014	2013	Mean (SD)
Test Weight (lb/bu)	64 (1)	63 (1)	63 (2)	64 (1)	62 (2)	64 (2)	63 (1)
1000 Seed Wt (g)	222 (31)	214 (30)	231 (27)	220 (32)	211 (38)	235 (29)	222 (10)
Water Hydration Capacity (%)	102 (8)	102 (5)	95 (6)	110 (18)	99 (13)	94 (11)	100 (6)
Unhydrated Seeds (%)	0 (2)	1 (1)	2 (4)	2 (2)	2.0 (2)	8 (9)	3 (3)
Swelling Capacity (%)	146 (14)	150 (9)	135 (16)	147 (14)	149 (13)	*	nd
Cooked Firmness (N/g)	21.7 (5)	25 (6)	22 (5)	22 (6)	*	*	nd

*data not reported; nd = not determined

measure hydration properties by measuring water hydration capacity, percentage of unhydrated seeds and swelling capacity.

Water hydration capacity of dry peas ranged from 80 to 150%, with a mean of 103% (Table 9). The 2018 mean value is comparable to the 5-year mean of 101%. Peas from individual harvest years had slightly lower hydration capacity compared to 2018, except for the peas evaluated in 2017. The mean water hydration capacity in the green market class was four percentage points higher than the mean hydration capacity of the yellow market class (Table 10). The water hydration capacities in the green market class were similar across the previous five years except for peas from 2015. The yellow peas from 2018 had hydration capacities most similar to the peas from the 2014 and 2017 harvest years and slightly higher values compared to peas from 2013 and 2016. In the green market class, Icicle and PRO 7123 had the lowest (98%) and highest (113%) water hydration capacities, respectively. The water hydration capacity ranged from 90% in Salamanca (yellow) to 111% in Ewald (yellow) cultivars (Table 11).

Unhydrated seed percentage ranged from 0-11% with a mean of 1%, which is less than the 5-year mean unhydrated seed percentage (Table 9). Peas from the both market classes had unhydrated seed values of 0% (Table 10). Both market classes had fewer unhydrated seeds in 2018 compared to the 5-year mean value (Table 10). The majority of the green pea cultivars had unhydrated seed rates of 0 or 1% while Majorette had unhydrated seed rate of 2% (Table 11). CDC Meadows and Nette had unhydrated seed rates of 5%, the most among the peas tested. Overall, the low numbers (0-1%) 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 74% to 174% with a mean value of 147% (Table 9). The mean swelling capacity for peas from the 2018 harvest was similar to the values obtained in 2017, but was slightly lower than peas from the 2014 and 2015 harvest years. The swelling capacity of green peas was about 3 percentage points higher than the yellow pea market classes (Table 10), which is the opposite of that observed in 2017, but similar to

Table 11. Mean physical parameters of USA dry pea cultivars grown in 2018.

Market Class	Cultivar	Test Weight (lb/bu)	1000 Seed Wt (g)	Water Hydration Capacity (%)	Unhydrated Seeds (%)	Swelling Capacity (%)	Cooked Firmness (N/g)
Green	Arcadia	63	194	102	1	139	21.7
	Ariel	63	181	105	0	143	20.8
	Banner	64	171	109	1	160	17.8
	CDC Greenwater*	64	260	103	0	158	12.4
	Ginny	63	193	104	1	141	23.6
	Hampton*	62	185	106	1	153	30.5
	Icicle*	62	115	98	0	126	28.0
	Majorette*	63	217	102	2	146	12.9
	PRO 7123	62	165	113	0	153	18.9
	Shamrock	64	204	111	0	156	16.9
	Unknown	63	210	103	0	146	19.5
Yellow	AAC Carver	64	237	101	0	153	21.2
	AC Earlystar	64	209	104	0	154	21.1
	Agassiz	62	233	101	0	140	19.2
	Bridger	65	224	99	1	146	19.9
	CDC Amarillo	64	233	100	1	144	18.4
	CDC Leroy*	64	131	107	1	150	13.7
	CDC Meadow	64	211	98	5	109	18.6
	DS Admiral*	62	241	97	0	144	27.0
	Ewald*	63	179	116	0	159	16.0
	Gunner*	64	220	92	0	132	26.0
	Korando	63	206	108	0	141	21.5
	Montech 4152*	65	227	111	0	157	20.6
	Montech 4193	63	217	108	0	159	25.6
	Mystique	63	282	94	1	131	26.9
	Nette	64	225	95	5	146	29.5
	Salamanca*	66	283	90	0	141	29.5
	Spider*	63	228	93	0	130	18.8
	Universal*	62	192	105	1	146	19.2
	Unknown	64	217	104	1	149	21.6

**Only one sample of cultivar tested

the observation in 2016. Variability in the swelling capacity among cultivars was observed (Table 11). Arcadia (green) and CDC Meadow (yellow) had the least swelling capacity while Banner (green) and Ewald and Montech 4193 (yellow) had the highest swelling capacities among the cultivars tested (Table 11).

The **cooked firmness** values of peas were slightly lower in the peas from 2018 compared to those of 2016 and 2017, but similar to cooked firmness values observed in 2015. The cooked firmness for all peas ranged from 12.2 to 33.9 N/g with a mean value of 21 N/g (Table 9). The cooked firmness of peas was slightly different between market classes (Table 10). The green peas had lower firmness values than those of the yellow peas. The value obtained in 2018 did not match any of the cooking firmness values from previous years. The cooked firmness values in yellow peas from 2018 were the same as those in yellow peas from 2015 and 2016, but lower than values from 2017. Among the green cultivars, Majorette had the lowest cooking firmness (12.9 N/g) while Hampton (30.5 N/g) was the firmest (Table 11). For yellow cultivars, Nette and Salamanca had the highest (29.5 N/g) cooking firmness (i.e. most firm) among the yellow cultivars tested while CDC Leroy (13.7 N/g) had the lowest cooked firmness (Table 11). 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 both market classes in 2017 indicated that the peas had L* values that were similar to the peas from 2016 and 2017, but were lower than peas from 2013 to 2015 (Table 12). This observation was true for both green and yellow peas, although L* values were slightly higher in yellow pea in 2018 compared to 2016 and 2017. This data indicates that the peas from the 2018 crop year were darker in color than those from previous years except in peas from the 2016 and 2017 crop years. The less negative value for red-green (i.e., “a” value) value in 2018 indicates a less green color than 2013-2015 samples, but slightly greener than peas from 2016 and 2017. The “b” value for green peas from 2018 was similar to peas from 2013 and 2016 and indicates a bluer compared to the peas from 2015 and 2017 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 in 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 2018 appear greener in color compared to those from 2017. For the yellow pea market class, the 2018 crop had similar lightness values to peas from 2016 and 2017, but were slightly darker than the peas from the 2013 to 2015 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 2018 had “a” values that were similar to “a” values in peas from the other crop years except 2014, indicating a pulse that was redder in color compared to a pea from 2014. The “b” values for yellow peas from 2018 were most similar to “b” values of peas from 2016 and 217 crop years. However, the yellowness of peas from 2018 was less than that of peas from 2013 and 2015, but yellower than peas from 2014. The higher “b” values combined with the “a” value on the red part of the scale indicates that the samples would be a light yellow in color. The lower “a” combined with a lower “b” values indicates that the pulses would be a darker yellow color. Therefore, the yellow peas in 2018 appeared light yellow compared to peas from 2014. However, the peas from 2018 would be similar in appearance to the peas from other harvest years (Table 12).

Table 12. Color quality of dry pea grown in the USA before and after soaking in water 16 hours, 2013-2018.

	Mean (SD) of green pea											
	Before soaking						After soaking					
Color Scale*	2018	2017	2016	2015	2014	2013	2018	2017	2016	2015	2014	2013
L (lightness)	51.68 (3.57)	52.69 (2.82)	52.01 (2.47)	62.32 (4.11)	61.99 (2.19)	66 (8)	45.49 (2.42)	47.52 (3.22)	46.86 (2.68)	57.83 (4.27)	55.12 (2.58)	59 (9)
a (red-green)	-1.92 (0.77)	-1.24 (1.15)	-0.98 0.86	-3.53 (1.48)	-2.10 (0.89)	-3.8 (1)	-6.16 (0.77)	-5.24 (1.91)	-5.14 (1.18)	-9.07 (3.87)	-7.95 (2.56)	-15 (4)
b (yellow-blue)	14.15 (1.49)	15.11 (1.51)	14.01 (1.26)	15.31 (1.52)	8.79 (0.84)	14 (2)	28.52 (2.65)	28.63 (2.74)	27.39 (1.82)	22.57 (6.28)	18.73 (2.56)	34 (4)
Color Difference	16.45 (2.53)	15.39 (2.64)	15.17 (2.02)	11.44 (5.34)	13.43 (1.15)	**						

	Mean (SD) of yellow pea											
	Before soaking						After soaking					
Color Scale	2018	2017	2016	2015	2014	2013	2018	2017	2016	2015	2014	2013
L (lightness)	58.76 (2.39)	58.73 (1.70)	57.29 (2.52)	71.33 (1.87)	65.83 (0.98)	71 (8)	59.96 (1.98)	60.56 (2.19)	69.51 (1.71)	68.00 (3.78)	64.76 (1.47)	77 (14)
a (red-green)	6.91 (0.99)	6.83 (1.34)	7.16 (0.84)	6.51 (0.79)	4.64 (0.43)	7.0 (1)	9.38 (0.98)	9.60 (2.38)	9.62 (0.90)	4.65 (1.73)	4.57 (0.33)	6.3 (5)
b (yellow-blue)	19.21 (1.53)	20.40 (1.92)	19.35 (1.37)	21.99 (2.23)	13.51 (1.20)	21 (2)	37.67 (2.65)	38.25 (4.44)	36.70 (2.55)	27.56 (5.19)	26.50 (3.36)	47 (6)
Color Difference	19.10 (2.95)	18.67 (3.64)	19.96 (2.52)	8.41 (5.24)	13.04 (2.37)	**						

*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.
**data not reported; color difference = change in value before soaking and after soaking

The color of the dry peas changed after the soaking process. The change in color was greater for green peas from the 2018 crop year compared to the other crop years (Table 12). 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 same trend occurred in the previous crop years. In 2018, lightness increased after soaking of the yellow peas, but to a lesser extent compared to previous pea samples. This is opposite of the decrease in lightness observed in yellow peas from 2014 and 2015. However, the general trend was that lightness increased in peas from other crop years. In addition, soaking decreased the greenness (i.e. higher “a” values) and increased yellowness (i.e. higher “b” values) of the yellow peas. This suggests that the peas appeared light yellow after soaking (Table 12). The color difference test indicates a general change in color after soaking or other process. The green market classes underwent less color change during soaking than did the yellow peas (Table 12). Although color difference is a general indicator of change, visual observations support an increase light green color in the green pea market class and minimal change in yellowness after the soaking process. The color difference values observed in 2018 were greater than those previously reported for green peas, but similar or greater than color differences in yellow peas from 2014 and 2015.

The Shamrock, Banner and PRO7123 cultivars from 2018 had the lowest L* value, the most negative (lowest) “a” value and the high “b” values. This resulted in peas with a blue green color. CDC Greenwater had the highest L* value and one of the lowest “a” values resulting in a light green colored pea. This pea was visually different from the Shamrock and Banner cultivars. Soaking reduced the L* value, caused the “a” value to become more negative (i.e., greener) and more yellow (i.e., increased “b” value). The greatest color difference was observed in the Ariel cultivar. This same cultivar also had the greatest color difference in 2017.

Table 13. Color quality of USA dry pea cultivars before and after soaking, 2018.

		Mean Color Values*						
		Before Soaking			After Soaking			
Market Class	Cultivar	L	a	b	L	a	b	Color Difference
Green	Arcadia	53.77	-1.70	13.28	46.57	-6.31	25.66	15.13
	Ariel	53.18	-2.15	12.90	44.70	-6.84	31.23	20.82
	Banner	48.02	-2.65	15.01	42.61	-6.88	30.73	17.28
	CDC Greenwater**	56.35	-1.27	11.79	47.72	-6.25	25.83	17.28
	Ginny	52.65	-1.76	14.04	47.56	-5.10	27.62	15.03
	Hampton**	52.26	-1.76	15.61	48.37	-5.12	27.47	13.05
	Icicle**	54.06	-1.01	14.44	45.76	-6.01	31.46	19.59
	Majorettes**	54.68	-1.41	12.60	49.63	-5.13	26.70	15.51
	PRO 7123	49.00	-3.38	15.25	42.57	-6.81	29.71	16.22
	Shamrock	46.01	-2.51	16.80	43.67	-5.82	30.76	14.78
	Unknown	54.74	-1.16	13.04	46.85	-6.13	26.92	16.91
Yellow	AAC Carver	58.43	7.91	19.64	60.04	10.46	38.28	19.01
	AC Earlystar	60.95	6.97	19.43	59.92	9.54	40.53	21.34
	Agassiz	60.42	6.12	17.41	58.28	7.91	33.78	18.46
	Bridger	58.12	6.89	19.18	59.43	9.13	38.06	18.42
	CDC Amarillo	58.33	7.97	20.58	60.20	9.02	37.11	16.41
	CDC Leroy**	57.14	5.63	18.88	58.11	9.37	40.62	22.08
	CDC Meadow	57.83	7.28	20.04	59.05	10.54	40.82	21.10
	DS Admiral**	58.14	7.08	18.88	59.31	10.19	38.19	19.60
	Ewald**	58.81	5.63	17.25	61.96	9.08	37.00	20.31
	Gunner**	56.89	9.81	21.66	61.15	11.49	35.33	14.43
	Korando	59.35	5.80	18.64	61.56	8.22	35.63	17.35
	Montech 4152**	60.44	5.79	18.34	60.71	9.58	40.01	22.01
	Montech 4193	53.11	6.14	18.92	61.30	8.74	36.92	22.97
	Mystique	59.38	7.79	19.65	62.06	8.25	31.58	12.75
	Nette	55.64	7.25	21.34	60.15	8.33	35.88	15.96
	Salamanca**	57.82	9.08	23.01	59.77	9.70	35.10	13.33
	Spider**	57.29	7.96	21.08	60.17	10.00	36.10	15.44
	Universal**	59.91	6.57	18.31	62.40	8.88	36.40	18.40
	Unknown	59.07	6.52	18.62	59.77	9.66	38.36	20.07

*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 cultivars of the yellow peas had L* values between 53.11 and 60.95, with AC Earlystar being the lightest and Montech 4193 being the darkest (Table 13). AC Earlystar was also the lightest yellow pea in 2017. CDC Leroy retained the darkest color after soaking while Universal became the lightest. Gunner had the highest redness ("a" value) score while the lowest was observed for the CDC Leroy and Ewald cultivars (Table 13). After soaking, Agassiz and Gunner had the lowest and highest redness scores, respectively. The yellowness of the dry yellow peas was greatest for Gunner and lowest for Ewald. After soaking, AC Earlystar had the highest yellowness values while Mystique had the lowest. The greatest color difference was observed in the Montech 4193 cultivar. The increase in lightness during soaking likely contributed to the greatest color difference. Salamanca had the least color change during soaking.

Pasting Properties
(Tables 14-16)

The peas from 2018 had peak, hot and cold paste viscosities and setback values that were most similar to peas from 2015 and 2017 and were similar to the 5-year average, but lower than the values of peas from 2014 and 2016 (Table 14). Mean peak time was slightly less than the 5-year mean value, but comparable to values from 2015 through 2017. Pasting temperature ranged from 70 to 82 °C, with a mean of 77.6°C. The mean value is comparable to peas from previous years. The pasting characteristics were similar between the green and yellow pea market classes, although yellow peas tended to have slightly higher values. Pea flour peak viscosities of 139 and 140 RVU were recorded for the green and yellow market classes,

Table 14. Starch characteristics of dry peas grown in the USA, 2012-2017.

Starch Characteristic	2018		2017	2016	2015	2014	2013	5-year
	Range	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Peak Viscosity (RVU)	92-175	139 (15)	139 (12)	146 (25)	136	143	141	141 (4)
Hot Paste Viscosity (RVU)	90-161	129 (13)	129 (10)	132 (18)	127	133	122	129 (4)
Breakdown (RVU)	1-26	10 (5)	10 (5)	14 (10)	8	10	20	12 (5)
Cold Paste Viscosity (RVU)	150-313	235 (33)	232 (31)	251 (58)	229	248	212	234 (16)
Setback (RVU)	54-164	105 (22)	103 (23)	119 (4)	102	115	91	106 (11)
Peak Time (Minute)	4-7	5 (0)	5 (1)	5 (1)	5	6	8	6 (1)
Pasting Temperature (°C)	70.2-82.4	77.6 (2.1)	76 (3)	76 (3)	77	78	*	nd

*data not reported; nd = not determined

Table 15. Starch characteristic of different market classes of dry peas grown in the USA, 2013-2018.

Starch Characteristic	Mean (SD) of green pea						5-year
	2018	2017	2016	2015	2014	2013	Mean (SD)
Peak Viscosity (RVU)	139 (15)	137 (12)	147 (23)	129 (19)	144 (25)	146 (17)	141 (8)
Hot Paste Viscosity (RVU)	128 (13)	127 (10)	131 (18)	122 (17)	135 (20)	122 (9)	127 (6)
Breakdown (RVU)	11 (5)	10 (5)	15 (9)	6 (5)	9 (7)	24 (15)	13 (17)
Cold Paste Viscosity (RVU)	228 (38)	231 (34)	253 (58)	219 (41)	252 (43)	218 (27)	235(17)
Setback (RVU)	101 (27)	104 (25)	122 (43)	97 (25)	118 (26)	96 (23)	107 (12)
Peak Time (Minute)	5 (1)	5 (1)	5 (1)	6 (1)	6 (1)	8 (0.3)	6 (1)
Pasting Temperature (°C)	78 (2)	78 (2)	76 (2)	78 (2)	78 (1)	*	nd

Starch Characteristic	Mean (SD) of yellow pea						5-year
	2018	2017	2016	2015	2014	2013	Mean (SD)
Peak Viscosity (RVU)	140 (14)	140 (12)	145 (27)	140 (19)	140 (26)	136 (19)	140 (3)
Hot Paste Viscosity (RVU)	131 (12)	130 (10)	132 (19)	130 (15)	128 (18)	122 (19)	128 (4)
Breakdown (RVU)	9 (5)	10 (5)	13 (10)	10 (5)	12 (10)	17 (11)	12 (3)
Cold Paste Viscosity (RVU)	238 (29)	233 (28)	249 (60)	234 (39)	237 (45)	207 (42)	232 (15)
Setback (RVU)	108 (19)	103 (20)	117 (44)	104 (26)	108 (30)	85 (26)	103 (12)
Peak Time (Minute)	5 (1)	5 (1)	5 (1)	5 (1)	6 (1)	8 (0)	7 (2)
Pasting Temperature (°C)	77 (2)	78 (2)	75 (4)	76 (4)	77 (2)	*	nd

*data not reported; nd = not determined

respectively (Table 15). Green peas from 2016 had higher peak viscosities than the peas from other harvest years, including peas from 2018. Hot and cold paste viscosities of green peas from 2018 were less than values in peas from 2014 and 2016, but greater than peas from other harvest years. The pasting characteristics of the yellow peas were most comparable to peas from 2015 and 2017. However, little variability pasting values were observed for yellow peas grown between 2014 and 2018 (Table 15). With the exception of peak viscosity, viscosity values for peas from 2018 were higher than the values for peas from 2013.

Within each market class, variability in starch characteristics was observed among cultivars. In the green market class, the Ariel cultivar had the highest peak, hot paste and cold paste viscosities (Table 16). In contrast, Banner and Hampton had the lowest peak, hot paste and cold paste viscosities. Icicle also tended to have lower viscosity values among the green peas. The breakdown of starch during heating was greatest in Majorettes and least in Shamrock. In 2017, Shamrock also had the least starch breakdown among cultivars tested. Gunner had the highest peak and hot paste viscosities among yellow cultivars. The lowest peak and hot paste viscosities of the peas in the yellow market class were observed in the CDC Leroy cultivar (Table 16). The highest cold paste viscosity value was observed for Gunner followed by Nette while the lowest cold paste viscosity was observed in the CDC Leroy cultivar. The breakdown of the paste during heating was greatest in Gunner and least for CDC Leroy cultivar. The 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 26 RVU, which represents little breakdown of the starch paste.

Table 16. Mean starch characteristics of dry pea cultivars grown in the USA in 2018.

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	Arcadia	149	136	13	249	114	5.22	77.5
	Ariel	160	145	15	279	135	5.17	77.6
	Banner	120	112	8	189	77	5.43	79.7
	CDC Greenwater*	142	136	6	242	106	5.47	76.7
	Ginny	135	123	12	214	91	5.17	79.0
	Hampton*	120	112	8	174	62	5.27	79.9
	Icicle*	126	114	12	188	74	5.60	80.0
	Majorettes*	143	128	16	235	108	5.27	77.4
	PRO 7123	138	126	12	202	75	5.17	79.1
	Shamrock	138	134	4	233	99	5.68	79.5
	Unknown	150	136	14	259	123	5.15	77.2
Yellow	AAC Carver	141	131	10	244	113	5.29	76.5
	AC Earlystar	146	138	8	245	107	5.27	77.0
	Agassiz	138	131	7	250	119	5.25	76.5
	Bridger	147	134	13	244	110	5.22	75.7
	CDC Amarillo	137	129	7	238	109	5.36	75.3
	CDC Leroy*	92	90	2	150	60	6.93	82.4
	CDC Meadow	130	126	4	232	106	5.40	78.3
	DS Admiral*	146	136	10	254	119	5.13	76.0
	Ewald*	120	119	2	200	81	6.07	82.3
	Gunner*	171	145	26	264	120	4.87	75.2
	Korando	125	119	6	187	69	5.33	79.1
	Montech 4152*	153	138	15	251	113	5.20	78.4
	Montech 4193	119	113	6	202	89	5.33	78.3
	Mystique	134	124	10	242	118	5.07	74.3
	Nette	153	141	13	262	121	5.12	76.3
	Salamanca*	137	119	19	233	114	4.87	74.3
	Spider*	140	133	8	226	93	5.20	74.2
	Universal*	116	113	4	198	85	5.47	79.2
	Unknown	142	132	9	241	109	5.30	77.5

*Only one sample of cultivar tested

Lentil Quality

Sample distribution

A total of 52 lentil samples were collected from Idaho, Montana, North Dakota and Washington between August and November 2018. Growing location, number of samples, market class, and genotype details of these lentil samples can be found in Table 17. Pardina represented all of the Spanish brown lentils while 19 of the 33 green lentils were the CDC Richlea cultivar. Redchief (4) was the most common red lentil evaluated in the survey.

Table 17. Description of lentils used in the 2018 pulse quality survey.

State	No. of Samples	Market class	Cultivars	
Idaho	16	Green	Brewer	Merrit
		Red	Redchief	
		Spanish Brown	Pardina	
Montana	13	Green	Avondale	CDC Richlea
			CDC Greenstar	CDC Viceroy
		Red	CDC Maxim	
		Spanish Brown	Pardina	
North Dakota	19	Green	Avondale	Eston
			CDC Richlea	NDSU Eagle
			CDC Viceroy	
		Red	CDC Maxim	
		Spanish Brown	Pardina	
Washington	4	Green	Brewer	Merrit
		Spanish Brown	Pardina	

Proximate composition of lentils (Tables 18-20)

Moisture

he moisture content of lentils ranged from 6.5 to 11.7% in 2018 (Table 18). The mean moisture content (8.4%) was lower than the 5-year mean of 8.8% and was most similar to the mean value of lentils from 2017, but lower than lentils from 2014 through 2016. Overall, all samples evaluated had moisture contents below the 13-14% recommended general storability.

The moisture contents of the different market classes were between 7.6 and 8.8% (Table 19). The green lentils had a mean moisture content of 8.8% while red and Spanish brown lentils had moisture contents of 7.6 and 7.8%, respectively. The green lentils from 2018 had lower moisture contents than the five previous years except 2013 but was identical to the 5-year mean moisture content. The 2018 red lentils had lower moisture contents than lentils from the previous five years except for lentils from 2013. The 5-year mean moisture content was one percentage unit higher than the lentils from 2018. Spanish brown lentils had a mean moisture content that was comparable to lentil from 2016, but lower than lentils from 2014, 2015 and 2017.

The highest moisture contents were observed in the CDC Greenstar (10.2%), CDC Richlea (9.2%) and Avondale (9.0%) cultivars (i.e., green lentils) while CDC Maxim (8.3%) cultivar in the red market class had the highest moisture content (Table 20). However, all lentils remained under the maximum moisture of 14%, which is necessary for storing pulses.

Ash

Ash content of lentils ranged from 2.0 to 3.8% with a mean of 2.9% (Table 18). The mean ash content of lentils grown in 2018 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 ash contents of the different market classes ranged between 2.6 and 2.8%, with red lentils having the highest ash content (Table 19). The Easton (green) cultivar had the highest (3.8%) ash content followed by Brewer and Merrit (green), CDC Redchief (red) and Pardina (Spanish brown) cultivars (Table 20). The lowest (2.3%) ash content was observed in the CDC Greenstar (green) cultivar.

Fat

Fat content of lentils ranged from 1.2 to 4.8% with a mean of 2.6% (Table 18). The fat content was measured in 2017 for the first time and peas from the 2017 harvest had lower (2.1%) mean fat contents then peas from 2018. Literature reports indicate that lentils have fat contents between 1 and 3%; therefore, the fat content of most of the lentils grown in 2018 fall within the range reported by others. Differences (~0.7 percentage points) in fat content were observed between the green lentils and the other two lentil market classes (Table 19). Easton (green) cultivar had the highest mean (4.0%) fat content while Pardina (Spanish brown) and CDC Maxim (red) had the lowest (2.0%) fat content among cultivars (Table 20).

Protein

Protein content of lentils averaged 24.4% in 2018 (Table 18). The protein content ranged from 18.7 to 28.8%. The mean protein content of lentils grown in 2018 was higher than lentils grown in 2013-2017 (i.e. 23-24%) and was higher than the 5-year mean value of 23.4%. The protein contents of the three market classes were different (Table 19). Red lentils had the highest mean protein content (26%) among lentil market classes while green and Spanish brown lentils had values of 24.2% and 24.3%, respectively. The Merrit (green) and CDC Greenstar (green) cultivars had the highest and lowest protein, respectively, among known cultivars (Table 20). Merrit also had the highest protein among cultivars in 2017.

Total starch

Total starch content of lentils ranged from 35.9 to 54.6%, with a mean of 44.0% (Table 18). The mean total starch content of lentils grown in 2018 was similar to the lentils from the 2014, 2016 and 2017 harvest years (i.e. 43-44%), but lower than the 5-year mean of 45.6%. The starch content of lentils from 2018 was less than those observed in 2013 (54%).

The starch contents of the green and Spanish brown market classes were 44.1 and 44.4%, respectively while the green market class had a mean starch content of 44.0% (Table 19). This indicates essentially no variability in starch content between market classes. However, some variation in starch content was observed between lentils from different crop years. The most notable differences existed between lentils from 2018 and lentils from the 2013 crop years (Table 19). Red and green lentils had mean starch contents that were most similar to lentils from 2014 and 2017 harvest years. The Spanish brown lentils had total starch contents that were higher than lentils from previous harvest years. The highest starch content was observed in CDC Richlea (green) followed by the CDC Greenstar (green) cultivar (Table 20). In contrast, these two cultivars had the lowest protein contents. The Merrit (green) cultivar had the lowest (38.4%) starch content among known cultivars tested (Table 20). Merrit also had the lowest starch content in both 2016 and 2017 crop years.

Table 18. Proximate composition of lentils grown in the USA, 2013-2018.

Proximate Composition (%)	2018 Range	2018 Mean (SD)	2017 Mean (SD)	2016 Mean (SD)	2015 Mean (SD)	2014 Mean (SD)	2013 Mean (SD)	5-year Mean (SD)
Moisture	6.5-11.4	8.4 (1.1)	8.8 (1.0)	9.0 (1.0)	9.7 (1.0)	10.5 (1.1)	5 (2)	8.8 (2.3)
Ash	2.0-3.8	2.6 (0.3)	2.5 (0.2)	2.5 (0.2)	2.7 (0.3)	2.5 (0.4)	2.4 (0.3)	2.6 (0.2)
Fat	1.2-4.8	2.6 (0.8)	2.1 (0.5)	*	*	*	*	nd
Protein	18.7-28.8	24.4 (1.9)	23.5 (1.7)	21.7 (1.6)	22.6 (1.2)	23.6 (1.5)	23 (2)	23.4 (1.1)
Total Starch	35.9-54.6	44.0 (2.9)	44.0 (2.0)	43.3 (3.1)	38.3 (2.7)	43.5 (3.2)	54 (6)	45.6 (7.1)

*= not reported; nd = not determined

Table 19. Proximate composition of different market classes of lentils grown in the USA, 2013-2018.

Market Class	Proximate Composition (%)	Mean (SD) 2018	2017	2016	2015	2014	2013	5-Year Mean (SD)
Green	Moisture	8.8 (1.1)	9.0 (0.8)	9.2 (0.9)	9.8 (1)	10.9 (1.2)	5 (1)	8.8 (2.2)
	Ash	2.6 (0.4)	2.4 (0.2)	2.5 (0.2)	2.9 (0.2)	2.4 (0.1)	2.3 (0.2)	2.5 (0.2)
	Fat	2.8 (0.8)	2.1 (0.5)	*	*	*	*	nd
	Protein	24.2 (2.0)	23.2 (1.7)	21.4 (1.5)	22.5 (1)	23.2 (1.5)	23 (3)	22.7 (1)
	Total Starch	44.1 (3.4)	44.0 (2.1)	43.3 (3.2)	38.5 (2)	44.6 (3.5)	55 (6)	45.1 (6)
Red	Moisture	7.6 (1.1)	8.6 (1.2)	9.3 (0.8)	10.4 (1)	10.0 (0.8)	5 (3)	8.7 (2.2)
	Ash	2.8 (0.1)	2.5 (0.2)	2.6 (0.2)	2.7 (0.4)	2.9 (0.6)	2.6 (0.4)	2.7 (0.2)
	Fat	2.1 (0.3)	2.0 (0.5)	*	*	*	*	nd
	Protein	26.0 (0.6)	24.3 (1.5)	23.3 (1.2)	22.8 (2)	24.2 (1.3)	25 (2)	23.9 (1)
	Total Starch	42.8 (1.2)	43.9 (2.0)	44.9 (1.8)	39.1 (2)	41.2 (0.6)	52 (5)	44.2 (4.9)
Spanish Brown	Moisture	7.8 (0.8)	8.2 (0.7)	7.8 (0.7)	8.9 (1)	9.7	*	nd
	Ash	2.6 (0.2)	2.7 (0.2)	2.5 (0.3)	2.9 (0.2)	2.2	*	nd
	Fat	2.0 (0.5)	2.2 (0.5)	*	*	*	*	nd
	Protein	24.3 (1.4)	23.6 (1.2)	20.7 (1.0)	22.8 (1)	22.2	*	nd
	Total Starch	44.4 (1.2)	43.9 (1.7)	41.1 (2.8)	36.8 (4)	42.5	*	nd

*= not reported; nd = not determined

Mineral composition of lentil (Tables 21-22)

Similar to dry peas, lentils mineral composition varied significantly depending on the element (i.e. mineral) analyzed. Potassium and phosphorus account for the highest amounts of minerals in the lentil samples (Table 21). The potassium contents of all samples ranged from 6439 to 9498 mg/kg, with a mean value of 7799 mg/kg. Phosphorus content ranged from 3950 to 6656 mg/kg, with a mean of 5438 mg/kg. Magnesium content in lentils fell between 890 and 1175 mg/kg and averaged 1019 mg/kg. Calcium content of all lentils was 484 mg/kg and varied from 390 to 653 mg/kg. Other minerals had similar variability, but to a lesser extent.

The potassium content of lentil classes from 2018 tended to be higher

Table 20. Mean proximate composition of lentil cultivars grown in the USA in 2018.

		Concentration (%)				
Market Class	Cultivar	Moisture	Ash	Fat	Protein	Starch
Green	Avondale	9.0	2.4	2.2	23.9	44.2
	Brewer	7.5	2.8	2.2	25.1	43.4
	CDC Greenstar*	10.2	2.3	2.3	22.4	45.3
	CDC Richlea	9.3	2.6	2.6	23.2	45.5
	CDC Viceroy	8.0	2.6	3.5	26.1	43.3
	Eston*	7.9	3.8	4.0	27.2	41.2
	Merrit	7.0	2.8	2.6	27.6	38.4
	NDSU Eagle*	8.8	2.5	2.5	25.1	41.6
Red	CDC Maxim	8.3	2.7	2.0	25.8	42.5
	Redchief	7.3	2.8	2.1	26.1	43.0
Spanish Brown	Pardina	7.8	2.6	2.0	24.3	44.1

*Only one sample of cultivar tested

Table 21. Mineral concentrations of lentils grown in the USA, 2013-2018.

Market Class	Mineral	2018 Mean (SD)	2017 Mean (SD)	2016 Mean (SD)	2015 Mean (SD)	2014 Mean (SD)	2013 Mean (SD)	5-year Mean (SD)
Green	Calcium	491 (67)	493 (69)	534 (67)	449 (54)	761 (89)	496 (81)	547 (124)
	Copper	8 (2)	9 (1)	6 (1)	7 (1)	7 (1)	7 (2)	7 (1)
	Iron	53 (19)	63 (10)	62 (14)	80 (38)	61 (9)	57 (18)	65 (9)
	Magnesium	1033 (64)	1048 (48)	1026 (67)	1149 (75)	789 (27)	597 (185)	922 (224)
	Manganese	15 (4)	14 (3)	12 (3)	13 (2)	17 (4)	15 (4)	14 (2)
	Phosphorus	5249 (716)	2632 (351)	3890 (744)	2625 (359)	2574 (156)	2931 (829)	2930 (555)
	Potassium	7714 (893)	7057 (450)	5401 (506)	6111 (791)	8493 (295)	6936 (1463)	6800 (1160)
	Zinc	33 (7)	37 (5)	25 (4)	27 (4)	40 (4)	35 (10)	33 (6)
	Selenium (µg/kg)	226 (46)	236 (54)	179 (33)	279 (32)	369 (37)	727 (382)	358 (218)
Red	Calcium	476 (52)	530 (102)	573 (92)	590 (177)	647 (38)	460 (56)	560 (70)
	Copper	9 (1)	9 (1)	7 (1)	7 (1)	7 (1)	7 (3)	7 (1)
	Iron	48 (25)	74 (12)	64 (12)	123 (90)	62 (5)	75 (28)	80 (25)
	Magnesium	1030 (57)	1016 (41)	1035 (87)	1145 (90)	772 (23)	677 (175)	929 (196)
	Manganese	18 (3)	15 (3)	15 (3)	15 (2)	13 (1)	20 (5)	16 (3)
	Phosphorus	5834 (301)	2906 (232)	3569 (625)	2695 (162)	2960 (177)	3909 (1491)	3208 (509)
	Potassium	8313 (884)	6808 (423)	5637 (939)	5962 (575)	8416 (730)	7761 (2607)	6917 (1175)
	Zinc	41 (6)	38 (6)	27 (7)	29 (6)	41 (6)	45 (16)	36 (8)
	Selenium (µg/kg)	193 (24)	223 (51)	189 (28)	269 (32)	397 (30)	379 (143)	291 (93)
Spanish Brown	Calcium	468 (34)	496 (40)	479 (64)	457 (34)	*	*	nd
	Copper	9 (1)	8 (1)	6 (1)	8 (1)	*	*	nd
	Iron	33 (15)	68 (14)	62 (21)	109 (43)	*	*	nd
	Magnesium	977 (41)	1036 (38)	934 (38)	1168 (75)	*	*	nd
	Manganese	15 (3)	16 (2)	10 (2)	14 (2)	*	*	nd
	Phosphorus	5736 (535)	3242 (151)	4722 (437)	3137 (289)	*	*	nd
	Potassium	7778 (487)	7304 (474)	4997 (303)	6609 (791)	*	*	nd
	Zinc	37 (7)	43 (2)	28 (4)	33 (5)	*	*	nd
	Selenium (µg/kg)	194 (37)	169 (15)	166 (32)	239 (47)	*	*	nd

*data not reported; nd= not determined

overall than the previous years except 2014(Table 21). The lentils from 2018 had mean potassium levels of 7714 mg/kg in green lentils to 8313 mg/kg in the red market class. Phosphorus content in Spanish brown lentils was approximately 5736 mg/kg while in red and green lentils the phosphorus contents were 5834 and 5249 mg/kg, respectively. The phosphorus contents of the 2018 lentils exceeded levels in lentils from previous years, regardless of market class (Table 21). Although the phosphorus levels did not follow previous trends, the high phosphorus levels observed in 2018 do agree with phosphorus concentrations in lentils rported in scientific literature. Calcium concentration in green lentils from 2018 was comparable to the calcium levels in lentils from 2013 and 2017 harvest years, but lower than the 5-year mean value. Red lentils from 2018 had calcium concentrations similar to the lentils from 2013, but lower than lentils from 2014-2017 harvest years, including the 5-year mean (Table 21). Calcium concentrations in the Spanish brown lentils was lower in 2018 compared to lentils from the 2016 and 2017 harvest years. Magnesium concentration in lentils from 2018 tended to be higher than the 5-year values, but generally lower than the content found in the lentils from 2015 and 2017, regardless of market class. Although, the concentration of Magnesium in lentils from 2016 were similar to values in the 2018 lentils, regardless of market class. The trace mineral (i.e., copper, manganese) concentration in lentils had values that were either similar or slightly higher than values from previous harvest years. The iron concentrations of lentils harvested in 2018 were lower than those values reported from previous years (2013-2017) and the 5-year mean iron value (Table 21). Mean selenium (other trace minerals) concentrations in lentils grown in 2018 were significantly lower than the mean zinc and selenium concentrations of lentils from 2013-2015, but comparable to lentils from 2017 and slightly higher than values reported for lentils from 2016.

The mineral content of lentil cultivars varied significantly for some of the individual minerals (Table 22). The macro minerals (i.e. calcium, magnesium, potassium, phosphorus) varied widely among cultivars. For example, Brewer had a calcium concentration of 414 mg/kg while CDC Richlea contained 510 mg/kg. The CDC Viceroy cultivar had a magnesium concentration of 973 mg/kg, which was nearly identical to the same Magnesium concentration observed in lentils from 2017. The highest Magnesium concentration was observed Merrit cultivar (1110 mg/kg). The Merrit and CDC Greenstar cultivars had the highest and lowest potassium concentrations, respectively (Table 22). The CDC Greenstar cultivar had a mean phosphorus concentration of 4417 mg/kg while 6299 mg/kg was observed in the Merrit cultivar. Merrit also had the highest phosphorus concentration in 2017 survey samples. Variability existed in the trace minerals, but to a lesser degree (Table 22). Iron concentrations ranged from 33 mg/kg in Pardina to 80 mg/kg in the Brewer cultivar while selenium ranged from 173 µg/kg in the Brewer cultivar to 259 µg/kg in the Avondale cultivar.

Physical parameters of lentils (Tables 23-27)

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 2018 and comparisons to the 5-year mean values when applicable.

Test weight ranged from 59-66 lbs/ bu with a mean of 62.9 lbs/bu. This mean value was slightly higher than the 5-year mean of 62 lbs/bu (Table 23). The test weight for all lentil samples harvested in 2018 was comparable to lentils harvested in previous years. The mean test weight of lentils in the Spanish brown market class was 3 to 4 percentage points higher than test weights of lentils from the red and green market classes (Table 24). Maximum test weight of 65.8 lbs/bu was observed for the CDC

Table 22. Mean mineral concentrations of lentil cultivars grown in the USA in 2018.

		Concentration (mg/kg)*								(µg/kg)
Market Class	Cultivar	Ca	Cu	Fe	K	Mg	Mn	P	Zn	Se
Green	Avondale	478	7	57	7236	998	13	4951	32	259
	Brewer	414	8	80	7730	991	18	5893	35	173
	CDC Greenstar**	493	6	60	6889	1007	12	4417	25	233
	CDC Richlea	510	8	49	7755	1042	15	5131	33	232
	CDC Viceroy	460	8	72	6913	973	16	4928	30	226
	Eston**	431	9	73	7256	1025	11	5665	29	229
	Merrit	505	12	32	9214	1110	20	6299	40	175
	NDSU Eagle*	445	7	56	7521	1032	8	5312	27	255
Red	CDC Maxim	477	8	69	7622	1007	16	5687	40	216
	Redchief	475	9	37	8659	1042	19	5908	42	181
Spanish Brown	Pardina	468	9	33	7778	977	15	5736	37	194

*mineral key: calcium (Ca), copper (Cu), iron (Fe), potassium (K), magnesium (Mg), manganese (Mn), Phosphorus (P), Zinc (Zn) and selenium (Se);
**Only one sample of cultivar tested

Viceroy cultivar. The Eston (green) and Pardina (Spanish brown) cultivars had the next highest values at approximately 65% (Table 25). The lowest mean test weight (59 lbs/bu) was found in the Merrit cultivar.

The range and mean **1000 seed weight** of of lentils grown in 2018 were 30 to 71 g and 42 g, respectively (Table 23). The mean value was lower than the 5-year mean of 44 g. Lentils of the red market class had a mean 1000 seed weight of 41 g, which was the same as the 5-yr average for red lentils. However, the mean 1000 seed weight for 2018 red lentils was higher than from lentil from the 2015 through 2017 crop year, but lower than the values of lentils from the 2013 and 2014 harvest years. In contrast, lentils of the green market class had a mean 1000 seed weight of 47 g, which is higher than the 5-year mean value (Table 24). However, green lentils from 2016 and 2017 had higher mean 1000 seed weights compared to the 2018 data. Lentils in the Spanish brown market class had mean 1000 seed weight that was higher than previous years. The individual cultivars varied extensively in 1000 seed weight. Eston had the lowest 1000 seed weight at 30 g, followed by Pardina (32 g) and CDC Viceroy (32 g). CDC Greenstar had the highest 1000 seed weight at 71 g. This sample was visually larger; however, only one sample was evaluated.

Water hydration capacity of lentils ranged from 71 to 118%, with a mean of 99% (Table 23). The 2018 mean water hydration capacity value was similar to lentils from 2017, higher than values in lentils from 2013, 2014, and 2016 but lower than lentils from 2015. The water hydration capacity (106%) was highest for red lentils followed by the green (100%) and Spanish brown (93%) market classes (Table 24). The water hydration capacities of the green and Spanish brown lentils were substantially lower than lentils from their respective classes in 2015. Green lentils had comparable

Table 23. Physical parameters of lentils grown in the USA, 2013-2018.

	2018		2017	2016	2015	2014	2013	5-year
Physical Parameters	**Range**	**Mean (SD)**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean (SD)**
Test Weight (lb/Bu)	59.0-66.1	62.9 (2.2)	62 (2)	62 (3)	62 (2)	61 (4)	62 (2)	62 (1)
1000 Seed Wt (g)	30-71	42 (9)	44 (9)	45 (9)	43 (9)	44 (12)	46 (6)	44 (1)
Water Hydration Capacity (%)	71-118	99 (2)	101 (3)	91 (11)	118 (7)	94 (4)	90 (20)	99 (12)
Unhydrated Seeds (%)	0-10	2 (3)	1 (2)	4 (7)	1 (1)	2 (1)	7 (8)	3 (3)
Swelling Capacity (%)	98-177	140 (15)	144 (28)	140 (28)	161 (33)	102 (17)	*	nd
Cooked Firmness (N/g)	9.7-22.1	15 (3)	14.9 (3.9)	13.4 (2.5)	11.9 (2)	*	*	nd

*data not reported, nd = not determined

Table 24. Physical parameters of different market classes of lentils grown in the USA, 2013-2018.

Market class	Physical Parameter	2018	2017	2016	2015	2014	2013	5-Year Mean
Green	Test Weight (lb/Bu)	62.2 (1.8)	61 (2)	62 (2)	62 (2)	63 (3)	63 (2)	62 (1)
	1000 Seed Wt (g)	47 (8)	48 (8)	49 (8)	47 (9)	32 (5)	45 (6)	44 (7)
	Water Hydration Capacity (%)	100 (9)	103 (10)	95 (9)	121 (18)	94 (4)	82 (22)	99 (15)
	Unhydrated Seeds (%)	1 (1)	1 (1)	2 (4)	1 (1)	3.0 (1)	11 (7)	4 (4)
	Swelling Capacity (%)	140 (15)	144 (18)	148 (26)	148 (32)	103 (9)	*	nd
	Cooked Firmness (N/g)	14.5 (3.8)	15.1 (4.4)	13.5 (2.8)	12.5 (2.0)	*	*	nd
Red	Test Weight (lb/Bu)	61.6 (2.1)	63 (3)	63 (4)	64 (1)	60 (3)	62 (1)	62 (2)
	1000 Seed Wt (g)	41 (5)	36 (6)	36 (3)	36 (2)	50 (9)	49 (7)	41 (7)
	Water Hydration Capacity (%)	106 (12)	95 (16)	87 (3)	98 (9)	95 (2)	89 (21)	93 (5)
	Unhydrated Seeds (%)	1 (1)	2 (2)	4 (3)	2 (1)	2.0 (1)	6 (8)	3 (2)
	Swelling Capacity (%)	143 (15)	132 (11)	125 (21)	155 (15)	105 (10)	*	nd
	Cooked Firmness (N/g)	15.2 (3.5)	14.9 (2.2)	13.2 (2.1)	12.0 (1.0)	*	*	nd
Spanish Brown	Test Weight (lb/Bu)	65.4 (0.6)	64 (2)	66 (1)	64 (2)	66	*	nd
	1000 Seed Wt (g)	32 (2)	40 (10)	36 (2)	38 (8)	36	*	nd
	Water Hydration Capacity (%)	93 (10)	102 (15)	79 (16)	124 (6)	91	*	nd
	Unhydrated Seeds (%)	6 (3)	3 (4)	13 (13)	1 (1)	2	*	nd
	Swelling Capacity (%)	137 (16)	144 (18)	118 (26)	191 (23)	115	*	nd
	Cooked Firmness (N/g)	15.5 (1.8)	13.6 (3.3)	13.1 (0.8)	10.8 (1.3)	*	*	nd

*data not reported; nd = not determined

water hydration capacity to green lentils grown in 2017 but had higher values than lentils harvested in other years. The red market class had a 2018 mean water hydration value that exceeded values in lentils from previous years. The Spanish brown market classes had mean water hydration capacities that were lower than lentils from 2015 and 2017, but higher than values from other previous crop years. The water hydration capacity ranged from 83% in CDC Viceroy (green) to 114% in Merrit (green). Most other cultivars ranged from 95 to 104% (Table 25).

Unhydrated seed percentage ranged from 0 to 10% with a mean of 2%, which was less than the 5-year mean of 3% (Table 23). The unhydrated seed percentage was lower in 2018 lentils compared to lentils from 2013 and 2016 harvest years. The amount of unhydrated seeds in all market classes varied from 1 to 6% (Table 24). The green and red lentils had lower values compared to the five-year mean values. The unhydrated seed count in the Spanish brown lentils from 2014, 2015 and 2017 had lower unhydrated seed amounts compared to the unhydrated seeds from 2018. A number of cultivars had no or one unhydrated seed percentages while Pardina had the highest at 6% (Table 25). The unhydrated seed numbers obtained in 2018, for specific cultivars, tended to be lower than these same cultivars harvested in 2017.

The **swelling capacity** of all lentils ranged from 98 to 177%, with a mean value of 140% (Table 23). The swelling capacity from 2018 samples was greater than that of lentils from the 2014 harvest year and similar to the lentils from 2016 and 2017, but lower than the swelling capacities of lentils from the 2015 harvest year. The swelling capacity of lentils was similar between market class with red lentils having a slightly higher swelling capacity (Table 24). Swelling capacities of 140% was observed in the green market class for lentils grown in 2018, which was less than the swelling capacities of green lentils from the 2015 through 2017 harvest years. Avondale had the greatest swelling capacity (150%) while NDSU Eagle had the lowest (109) among green cultivars (Table 25). A swelling capacity of 143 for lentils in the red market class was greater that red lentils from other harvest years except 2015. Redchief had a higher swelling capacity among the cultivars tested (Table 25). The Spanish brown Lentils had swelling capacities greater than lentils from 2014 and 2016 but lower than lentils from 2015 and 217.

The **cooked firmness** of all lentils ranged from 9.7 to 22.1 N/g with a mean value of 15 N/g (Table 23). The lentils from 2018 had slightly greater cooked firmness values than lentils from 2016 and 2015 but similar to lentils from the 2017 harvest year. The cooked firmness of lentils was not significantly different between market classes (Table 24), although green lentils were slightly less firm than lentils from the other market classes. However, the 2018 red and Spanish brown lentils from their respective market classes were firmer than lentils from 2015 through 2017. Among the cultivars, Eston had the lowest cooked firmness while CDC Greenwater was the firmest (Table 24).

Color quality was measured using L*, a, and b values and from these values a color difference can be determined on lentils before and after soaking (Table 26). Color quality for the green and Spanish brown market classes in 2018 indicated that the lentils had slightly lower L* values than in lentils from previous years. This data indicates that the lentils from the 2018 crop year were darker in color than those from previous years. In contrast, red lentils from 2018 were lighter than in previous years except 2013-2015 crop years. The lower "a" value (i.e., red-green 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 2018, the "a" value of 4.34 was lower in green lentils from 2018 compared to green lentils harvested in 2016 and 2017 but higher than the values obtained in green lentils from 2013 through 2015. This indicates that

Table 25. Mean physical parameters of USA lentil cultivars grown in 2018.

Market Class	Cultivar	Test Weight (lb/bu)	1000 Seed Wt (g)	Water Hydration Capacity (%)	Unhydrated Seeds (%)	Swelling Capacity (%)	Cooked Firmness (N/g)
Green	Avondale	62.1	48	102	0	150	15.8
	Brewer	60.8	49	104	3	142	18.2
	CDC Greenstar*	61.5	71	95	0	141	20.7
	CDC Richlea	62.1	47	100	1	144	13.9
	CDC Viceroy	65.8	32	83	3	116	10.6
	Eston*	64.7	30	91	3	133	9.9
	Merrit	59.2	54	114	1	146	18.2
	NDSU Eagle*	64.1	37	95	2	109	14.5
Red	CDC Maxim	61	36	96	4	133	15.01
	CDC Redcoat**	62	44	92	3	133	16.91
Spanish Brown	Pardina	65.4	32	93	6	137	15.5

*Only one sample of cultivar tested

the lentils from 2018 were slightly less green than the lentils from the 2013 through 2015 harvest years (Table 26). In the red lentil market class, the 2018 samples were less green based on the higher “a” values compared to red lentils from 2013 through 2015. The lentils had comparable greenness to the lentils from 2017 and more greenness than that of the 2016 crop (Table 26). The Spanish brown “a” value was lower in the 2018 samples compared to brown lentils from 2016 and 2017; therefore, indicating less redness in the sample. The “b” value for green lentils from 2018 were comparable to the lentils from previous years except 2013. This indicated a s similar yellowness compared to the previous years. The “b” value for red lentils from 2018 indicated a yellower color compared to lentils from the previous crop years.

The color of the lentils changed after the soaking process. All market classes became lighter as evidenced by the higher L* values (Table 26) compared to pre-soaked lentils. This same trend occurred in previous years for all market classes. However, the greatest increase in lightness was found in the Spanish brown market class. 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 trend to increasing redness was observed in lentil from prior years after soaking, this same trend occurred in 2018. The Spanish brown redness value also increased upon soaking of the lentil. Lentils from all market classes became more yellow (i.e., increased b value) after soaking. The color changes in lentil samples was the greatest for the Spanish brown market classes (Table 26). The color difference value in green lentils was similar to the values observed in 2016 and 2017 harvest years. The color difference value for the red market class was the second lowest among the lentils from the previous years, indicating greater color stability among these lentils.

Among the cultivars, Pardina had the lowest L* value followed by CDC Maxim (Table 27). The highest L* was CDC Greenstar. This follows expectations that the brown lentils would be darker than the green lentils. The L* value of lentil increased after soaking with Brewer and CDC Viceroy CDC Greenstar having the highest values (Table 27). 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 and brown cultivars increased during soaking. Easton had the greenest color after soaking while CDC Maxim had the highest red value. The “b” value increased substantially in all lentils during soaking. The green lentil cultivar NDSU Eagle had the highest “b” value (i.e. yellowness) of the soaked lentils.

Table 26. Color quality of lentils grown in the USA before and after soaking, 2013-2018.

	Mean (SD) of green lentils											
	Before soaking						After soaking					
Color scale*	2018	2017	2016	2015	2014	2013	2018	2017	2016	2015	2014	2013
L (lightness)	53.97 (3.25)	56.13 (2.29)	55.22 (1.19)	57.14 (5.76)	63.12 (0.93)	60 (2)	57.69 (1.36)	57.26 (2.1)	58.23 (2.01)	62.29 (1.18)	59.91 (2.28)	67 (7)
a (red-green)	4.34 (1.21)	5.32 (1.15)	4.69 (1.42)	2.49 (2.17)	2.25 (1.56)	1 (2)	3.86 (1.34)	4.71 (1.24)	4.06 (1.42)	0.59 (1.79)	0.59 (2.19)	-0.2 (2)
b (yellow-blue)	21.28 (1.51)	22.11 (1.46)	23.16 (1.38)	19.55 (5.02)	15.36 (0.22)	23 (1)	30.73 (2.39)	31.98 (2.60)	32.30 (2.60)	28.30 (1.62)	25.79 (2.15)	35 (6)
Color Difference	10.54 (3.35)	10.42 (1.85)	9.82 (1.96)	6.18 (1.62)	11.10	**						

	Mean (SD) of red lentils											
	Before soaking						After soaking					
Color scale*	2018	2017	2016	2015	2014	2013	2018	2017	2016	2015	2014	2013
L (lightness)	51.13 (4.17)	46.19 (3.87)	45.95 (1.70)	56.84 (5.35)	56.06 (0.54)	54 (8)	53.01 (3.24)	48.95 (3.12)	49.54 (0.75)	52.51 (0.60)	51.82 (0.16)	57 (8)
a (red-green)	7.38 (0.50)	7.40 (1.28)	7.97 (0.63	3.71 (1.63)	4.19 (0.69)	5.4 (1)	13.63 (1.12)	12.63 (2.99)	13.84 (1.08)	8.64 (0.22)	7.83 (0.32)	10 (2)
b (blue-yellow)	21.28 (1.51)	13.93 (2.82)	14.34 (1.34)	18.58 (4.60)	7.57 (1.20)	15 (4)	28.44 (2.11)	28.18 (2.89)	27.04 (1.85)	20.29 (1.45)	21.98 (0.58)	28 (7)
Color Difference	13.02 (3.76)	15.89 (2.89)	14.51 (2.04)	6.37 (2.22)	15.46	**						

	Mean (SD) of brown lentils											
	Before soaking						After soaking					
Color scale*	2018	2017	2016	2015	2014	2013	2018	2017	2016	2015	2014	2013
L (lightness)	42.71 (6.78)	44.59 (3.55)	42.92 (1.12)	55.71 (5.26)	54.5	**	49.42 (1.75)	48.84 (3.04)	47.88 (1.69)	51.21 (2.82)	54.3	**
a (red-green)	5.01 (0.63)	6.11 (1.02)	5.21 (0.20)	3.43 (2.79)	2.2	**	7.08 (0.39)	7.66 (1.04)	6.59 (0.45)	4.66 (0.69)	0.99	**
b (yellow-blue)	12.35 (1.57)	13.18 (2.50)	12.07 (0.94)	17.95 (4.79)	6.65	**	29.33 (2.55)	28.52 (3.85)	26.59 (1.31)	19.54 (1.84)	23.91	**
Color Difference	19.01 (5.74)	16.16 (4.43)	15.56 (1.12)	5.25 (1.06)	17.30	**						

*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.
**data not reported; color difference = change in value before soaking and after soaking

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 Pardina cultivar (Table 27). The increase in redness and yellowness during soaking likely contributed to the greatest color difference in this cultivar. The color of Eston was the most stable as this cultivar had the lowest color difference value.

Pasting properties
(Tables 28-30)

Peak viscosity, hot and cold paste viscosities and setback values of lentils grown in 2018 were comparable to lentils from 2016 and 2017. Lentils from other harvest years had viscosity lower pasting values than lentils from 2018 (Table 28). Mean peak time was for lentils in 2018 was less than the 5-year mean value, but was similar to peak times measured in lentils from 2014, 2015 and 2017 harvest years. Pasting temperature ranged from 74 to 78°C, with a mean value of 77.8 °C, which is similar to the pasting temperatures of lentils from 2015 and 2017. The pasting characteristics were similar among the green and Spanish brown lentil market classes (Table 29) and were greater than the pasting values obtained for lentils in the red market class. For example, cold paste viscosities of 248, 214 and 253 RVU were recorded for the green, red and Spanish brown market classes, respectively (Table 29). The pasting characteristics of the lentils from their respective market classes were similar to values from 2016 and 2017, but greater than those from the 2013, 2014 and 2015 harvest years.

Variability in pasting characteristics were observed among cultivars (Table 30). In the green market class, the variability among cultivars was noticeable. Merrit had the lowest peak (104 RVU), hot paste (103 RVU), and cold paste (182 RVU) viscosities among the green lentil cultivars. In 2017, Merrit also had the lowest viscosity values. In contrast, CDC Greenstar had the highest viscosity values (Table 30). The red lentil cultivars had similar peak, hot paste and cold paste viscosities.

Table 27. Color quality of USA lentil cultivars before and after soaking, 2018.

		Mean Color Values*						
		Before Soaking			After Soaking			Color
Market Class	Cultivar	L	a	b	L	a	b	Difference
Green	Avondale	54.98	4.7	21.7	57.70	3.94	31.66	10.43
	Brewer	53.76	6.7	20.2	58.90	6.25	28.77	10.06
	CDC Greenstar**	56.68	4.54	22.37	57.16	3.40	30.87	8.63
	CDC Richlea	53.95	3.78	21.69	57.80	3.42	31.26	10.80
	CDC Viceroy	54.41	3.69	22.02	58.56	2.99	30.75	9.97
	Eston**	53.07	3.81	20.13	55.58	2.31	24.23	5.05
	Merrit	53.18	6.62	18.61	56.31	6.25	29.48	11.52
	NDSU Eagle*	51.04	4.94	20.15	57.11	4.64	31.70	13.07
Red	CDC Maxim	45.79	7.22	13.43	49.15	14.15	28.64	17.09
	Redchief	53.79	7.46	19.37	54.94	13.36	28.33	10.99
Spanish Brown	Pardina	42.71	5.01	12.35	49.42	7.08	29.33	19.02

*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

Table 28. Starch characteristics of lentils grown in the USA, 2012-2018*.

	2018		2017	2016	2015	2014	2012	5-year
Starch Characteristic	Range	Mean (SD)	Mean	Mean	Mean	Mean	Mean	Mean (SD)
Peak Viscosity (RVU)	86-166	142 (18)	143 (17)	148 (20)	124 (17)	121 (17)	119 (15)	131 (13)
Hot Paste Viscosity (RVU)	84-154	134 (14)	136 (15)	133 (18)	119 (15)	115 (13)	112 (12)	123 (11)
Breakdown (RVU)	1-21	8 (6)	7 (4)	15 (6)	4 (4)	6 (5)	7 (6)	8 (4)
Cold Paste Viscosity (RVU)	150-307	245 (29)	253 (28)	239 (31)	205 (25)	196 (24)	208 (25)	220 (24)
Setback (RVU)	66-157	111 (16)	117 (16)	106 (16)	86 (13)	81 (14)	96 (15)	97 (15)
Peak Time (Minute)	4.80-7.00	5.85 (0.76)	5.65 (1)	5.16 (0.26)	6 (1)	6 (1)	9.9 (1.4)	6.54 (1.91)
Pasting Temperature (°C)	74.3-81.6	77.8 (1.8)	77.8 (2)	75.9 (1.0)	77 (3)	76 (1)	**	nd

*data not reported in 2013; **not reported; nd = not determined

Table 29. Starch characteristic of different market classes of lentils grown in the USA, 2012-2018*.

Market class	Physical Parameter	Mean (SD) 2018	2017	2016	2015	2014	2012	5-Year Mean (SD)
Green	Peak Viscosity (RVU)	145 (18)	146 (16)	149 (22)	127 (17)	131 (12)	121 (14)	135 (12)
	Hot Paste Viscosity (RVU)	134 (14)	138 (13)	132 (20)	121 (14)	122 (9)	114 (11)	125 (10)
	Breakdown (RVU)	10 (6)	8 (5)	17 (6)	6 (5)	9 (5)	7 (7)	9 (4)
	Cold Paste Viscosity (RVU)	248 (30)	256 (5)	237 (35)	208 (25)	205 (25)	212 (3)	224 (22)
	Setback (RVU)	113 (17)	118 (16)	105 (18)	87 (14)	83 (17)	98 (15)	98 (14)
	Peak Time (Minute)	5.59 (0.16)	5.58 (0.47)	5.10 (0.20)	6 (1)	5 (0)	10 (1)	6 (2)
	Pasting Temperature (°C)	77.3 (2.0)	77.7	76.0 (1.0)	77 (4)	76 (1)	**	nd
Red	Peak Viscosity (RVU)	122 (8)	134 (19)	141 (13)	112 (23)	106 (9)	99 (13)	118 (18)
	Hot Paste Viscosity (RVU)	121 (8)	129 (17)	132 (14)	108 (20)	104 (9)	96 (13)	114 (16)
	Breakdown (RVU)	1 (0)	5 (4)	9 (3)	4 (3)	2 (1)	4 (5)	5 (3)
	Cold Paste Viscosity (RVU)	214 (17)	241 (32)	238 (18)	190 (33)	181 (14)	180 (30)	206 (31)
	Setback (RVU)	93 (9)	112 (19)	106 (12)	82 (15)	77 (6)	84 (20)	92 (16)
	Peak Time (Minute)	6.57 (0.65)	5.85 (0.65)	5.47 (0.24)	6 (1)	6 (1)	11 (2)	7 (2)
	Pasting Temperature (°C)	79.0 (1.3)	78.1 (1.4)	75.9 (1.2)	76 (1)	77 (1)	**	nd
Spanish Brown	Peak Viscosity (RVU)	143 (15)	150 (12)	148 (14)	123 (10)	131 (12)	**	nd
	Hot Paste Viscosity (RVU)	139 (12)	144 (10)	135 (17)	121 (10)	122 (9)	**	nd
	Breakdown (RVU)	5 (3)	6 (3)	14 (4)	2 (1)	9 (5)	**	nd
	Cold Paste Viscosity (RVU)	253 (22)	264 (19)	247 (26)	210 (20)	205 (25)	**	nd
	Setback (RVU)	114 (11)	120 (11)	113 (12)	89 (11)	83 (17)	**	nd
	Peak Time (Minute)	6.19 (0.84)	5.59 (0.27)	5.13 (0.26)	6 (1)	5 (0)	**	nd
	Pasting Temperature (°C)	78.2 (1.3)	78.0 (0.8)	75.7 (0.8)	79 (1)	76 (1)	**	nd

*data not reported in 2013; **not reported; nd = not determined

Table 30. Mean starch characteristics of lentil cultivars grown in the USA in 2018.

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	138	130	8	242	113	5.49	77.8
	Brewer	135	133	3	250	117	5.80	78.8
	CDC Greenstar*	157	144	13	268	124	4.93	75.0
	CDC Richlea	153	140	12	260	120	5.40	77.0
	CDC Viceroy	145	133	11	233	100	5.44	75.3
	Eston*	152	139	13	250	111	5.67	76.7
	Merrit	104	103	1	182	79	6.64	81.0
	NDSU Eagle*	124	123	1	230	107	6.87	78.4
Red	CDC Maxim	122	121	2	212	92	6.33	78.3
	Redchief	122	122	1	214	94	6.68	79.4
Spanish Brown	Pardina	143	139	5	253	114	6.19	78.4

* Value from only one sample.

Chickpea Quality

Sample distribution

A total of 79 chickpea samples were col- lected from Idaho, Montana, North Dakota, South Dakota, and Washington between July and October 2018. Growing location, number of samples, market class, and genotype details of these dry chickpea samples are provided in Table 31. CDC Orion (23), Sierra (17) and Sawyer(12) accounted for the majority of the chickpea evaluated.

Table 31. Description of chickpea samples used in the 2018 pulse quality survey.

State	No of samples	Market class	Cultivars	
Idaho	25	Kabuli	Bronic Sawyer	Sierra
Montana	23	Kabuli	CDC Frontier CDC Orion Marvel	Sawyer Sierra
North Dakota	17	Kabuli	CDC Frontier	CDC Orion
South Dakota	1	Kabuli	CDC Orion	
Washington	13	Kabuli	Dylan CDC Frontier HB14 Nash	CDC Orion Sawyer Sierra Sawyer

Proximate composition of chickpea (Tables 32-33)

The **moisture content** of chickpeas ranged from 6.7 to 11.6% in 2018 (Table 32). The mean moisture content of the samples was 8.8%, which is slightly higher than the 5-year mean of 8%. Chickpeas grown in 2018 had a mean moisture content that was similar to chickpeas grown in 2015, 2016 and 2017, but lower than the 2014 mean moisture content of 11%. CDC Orion had the highest moisture content at 9.1% while the Marvel cultivar had the lowest moisture (7.3%). The moisture contents of all samples were below the 13% recommended for general storability.

Ash content of chickpeas ranged from 2.0 to 3.3% with a mean of 2.8% (Table 32). The mean ash content of chickpeas grown in 2018 was comparable to ash contents of chickpea from other previous harvest years. CDC Orion and Dylan had the lowest ash content at 2.6% while Nash and Marvel had the highest ash contents at 3.0% (Table 33).

Chickpeas mean **fat content** was 7.2% and ranged from 4.9 to 9.7% (Table 32). Literature reports indicate that chickpea has a fat content between 2 and 7%; therefore, the fat content of chickpeas grown in 2018 fall within the range reported by others but was slightly higher than the fat content recorded in 2017. CDC Orion had the highest (7.9%) fat contents while Nash had the lowest (4.9%) fat content (Table 33).

Protein content of chickpeas ranged from 16.5 to 26.2%, with a mean of 20.8% (Table 32). The mean protein content of chickpea grown in 2017 was similar to the 5-year mean of 21%. Dylan had the lowest (17.3%) protein content while Marvel had the highest at 25.6% (Table 33). Growing conditions may have impacted protein content as the variability in protein was higher than in 2017.

Total starch content of chickpeas ranged from 31.3 to 45%, with a mean of 41.1% (Table 32). The mean total starch content of chickpeas grown in 2018 was similar (i.e. 41%) to the mean starch content observed in chickpea from the 2015 harvest year, but lower than the 5-year mean of 45%, primarily due to the higher starch composition observed in 2013 (53%). The Marvel cultivar had the lowest (34.7%) starch content while the highest (42.5%) was observed in the HB-14 cultivar.

Table 32. Proximate composition of Kabuli chickpeas grown in the USA, 2013-2018.

Proximate Composition**	Year							5-year
	2018		2017	2016	2015	2014*	2013	
	Range	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Moisture (%)	6.7-11.6	8.8 (0.9)	8.5 (0.9)	8.7 (1.7)	9 (1)	11 (1)	3 (2)	8 (3)
Ash (%)	2.0-3.3	2.8 (0.2)	2.8 (0.3)	2.7 (0.1)	2.7 (0.1)	2.5 (0.2)	2.8 (0.2)	2.7 (0.1)
Fat (%)	4.9-9.7	7.2 (1.1)	6.0 (0.4)	***	***	***	***	nd
Protein (%)	16.5-26.2	20.8 (2.3)	19.5 (2.0)	18.3 (1.4)	19 (1)	20 (2)	21 (2)	21 (1)
Starch (%)	31.3-45.0	41.1 (2.5)	39.6 (2.0)	40.0 (4.2)	41 (5)	42 (1)	53 (6)	45 (6)

*2014 data is for Frontier cultivar only; **composition is on an "as is" basis;***not reported; nd= not determined

Mineral composition of chickpea (Tables 34-35)

Similar to other pulses, chickpea **mineral composition** varied significantly depending on the element (i.e. mineral) analyzed. Potassium and phosphorus account for the highest amounts of minerals in the chickpea samples (Table 34). The potassium concentration of chickpea was 8405 mg/kg in 2018, this values is more than the 5-year mean. However, the mean potassium concentration of chickpeas from 2018 was less than the mean potassium contents in chickpea from 2013 and 2014. Phosphorus concentration in chickpea from 2018 was well below the phosphorus content of chickpeas from 2013, but similar to the phosphorus contents of chickpeas from the other harvest years. Both calcium and magnesium contents were higher in chickpea grown in 2018 compared to the 5-year mean calcium and magnesium values (Table 34). The trace minerals (copper, iron, manganese and zinc) of chickpeas harvested in 2018 tended to be similar to the values of chickpea from previous harvest years. Zinc concentration was higher than the 5-year mean values (Table 34). Mean selenium (another trace mineral) content of chickpeas grown in 2018 was significantly higher than the mean selenium contents of chickpeas from the 2015 through 2017 harvest years. However, the selenium content for chickpeas from 2018 was lower than the chickpeas harvested in 2013 and 2014. This likely is the result of the increased number of chickpea samples evaluated in recent years and the more diverse growing locations of the chickpeas obtained for the evaluation.

Although some differences were observed, copper, iron, manganese and zinc contents, in general, were com- parable among cultivars tested (Table 35). The Dylan cultivar contained the highest (948 mg/kg) concentration of calcium while the Sierra cultivar contained the lowest (649 mg/kg). The CDC Orion cultivar contained the lowest (7942 mg/kg) amount of potassium while the Nash cultivar had the highest (8554 mg/kg) potassium concentration. Phosphorus concentrations were lowest (2530 mg/kg) and highest (3215 mg/kg) in CDC Orion and Marvel, respectively (Table 35). Bronic and Marvel cultivars had the lowest (1225 mg/kg) and highest (1327 mg/kg) concentrations of magnesium, respectively. The selenium content ranged from 169 µg/kg in the Nash cultivar to 308 µg/kg in the Marvel cultivar. Regardless of the specific mineral, the composition of minerals in chickpeas was high and can contribute significantly to dietary mineral requirements.

Table 33. Mean proximate composition of chickpea cultivars grown in the USA, 2018.

	Concentration (%)				
Cultivar	**Moisture**	**Ash**	**Fat**	**Protein**	**Starch**
Bronic	8.8	2.9	7.3	21.2	41.7
CDC Frontier	8.6	2.7	6.6	22.3	38.5
CDC Orion	9.1	2.6	7.9	19.6	41.6
Dylan*	7.9	2.6	6.2	17.3	42.3
HB14*	8.3	2.9	6.8	19.8	42.5
Marvel	7.3	3.0	6.2	25.6	34.7
Nash*	8.7	3.1	4.9	17.9	40.9
Sawyer	8.7	2.9	6.7	21.6	41.5
Sierra	8.7	2.8	7.2	20.9	41.0
Unknown	9.3	2.8	7.5	21.1	41.4

* Only one sample of cultivar tested

Physical parameters of chickpeas (Tables 36-39)

Test weight, 1000 seed weight, water hydration capacity, percentage unhydrated seeds, swelling capacity, cooked firmness and color represent the physical parameters used to define physical quality. The data presented includes the range and mean value for 2018 and comparisons to the 5-year mean value.

Table 34. Mineral concentrations of chickpeas grown in the USA, 2013-2018.

	Year						
Micronutrient (mg/kg)	**2018 Mean (SD)**	**2017 Mean (SD)**	**2016 Mean (SD)**	**2015 Mean (SD)**	**2014* Mean (SD)**	**2013 Mean (SD)**	**5-year Mean**
Calcium	736 (114)	862 (136)	667 (154)	552 (114)	695 (75)	499 (238)	655 (141)
Copper	7 (1)	7 (1)	6 (1)	7 (1)	6 (1)	8 (2)	7 (1)
Iron	44 (7)	51 (7)	41 (4)	48 (3)	46 (5)	51 (11)	47 (4)
Magnesium	1264 (53)	1265 (36)	1226 (114)	1188 (48)	900 (8)	1148 (88)	1145 (144)
Manganese	36 (8)	41 (9)	35 (6)	29 (4)	33 (5)	44 (8)	36 (6)
Phosphorus	2797 (307)	2669 (227)	2882 (304)	2672 (189)	2642 (173)	3992 (1050)	2971 (579)
Potassium	8405 (546)	7863 (573)	5928 (642)	7558 (362)	10,077 (372)	9670 (1340)	8219 (1686)
Zinc	31 (6)	30 (5)	21 (2)	28 (7)	35 (4)	38 (9)	30 (7)
Selenium (µg/kg)	270 (75)	221 (60)	173 (40)	227 (43)	376 (30)	520 (264)	303 (143)

*2014 data is for Frontier cultivar only

Test weight ranged from 57-65 lbs/bu with a mean of 62 lbs/bu. This mean value is approximately the same as the 5-year mean of 61 lbs/bu (Table 36). The test weights of individual cultivars ranged from 59 lbs/bu in Dylan to 64.9 lbs/bu in the Marvel cultivar. The range and mean **1000 seed weight** of chickpeas grown in 2018 were 195-591 g and 410 g, respectively (Table 36). The mean value was approximately the same as the 5-year mean of 411 g. The Nash cultivar had a highest 1000 seed weight at 538 g while the marvel cultivar had the lowest value at 229 g (Table 37).

Water hydration capacity of chickpeas ranged from approximately 69 to 128%, with a mean of 102% (Table 36). The water hydration capacity of chickpeas from 2018 was essentially the same as the 5-year mean of 104%. The Nash cultivar had the highest water hydration capacity (118%) while CDC Orion had the lowest (96%) (Table 37). **Unhydrated seed percentage** ranged from 0-1% with a mean of 0%, which was less than the 5-year mean of 1% (Table 36). All of the cultivars had 0% mean unhydrated seed values and only a few samples had unhydrated seeds after soaking (Table 37). The **swelling capacity** of chickpeas ranged from 89 to 166%, with a mean value of 130% (Table 36). The mean value was similar to chickpeas from 2017 and were higher than those reported in 2014, but lower than swelling capacities of chickpeas from 2015 and 2016. The Marvel cultivar had the greatest swelling capacity at 155% while the Sierra cultivar had the lowest (119%). The swelling capacity of CDC Frontier cultivar has been evaluated since 2014. The swelling capacity of 105% (2014), 116% (2016), 134 (2018), 136% (2017) and 138% (2015) were observed over the 5-year period. The **cooked firmness** was new for 2015 and thus comparisons are based on four years. The cooked firmness of all chickpea ranged from 17.7 to 44.6 N/g, with a mean value of 27.9 N/g (Table 36). The firmness of chickpea from the 2018 crop was slightly firmer than the chickpeas from 2015, 2016 and 2017, which had mean firmness values of 19.7, 22.0 and 26.0 N/g, respectively. Although different, it is unlikely that consumers could detect this small difference. Among the cultivars, HB-14 had the lowest cooked firmness while the Nash cultivar was the firmest (Table 37).

Color quality was measured using L*, a, and b values and from these values a color difference was determined on chickpeas before and after soaking (Table 38). **Color quality** indicated that the lightness (i.e., L*) of the chickpeas from 2018 was lower than the chickpea from previous years except chickpeas from 2016 (Table 38). In 2018, the "a value of 9.06 was lower than values from 2013, comparable to 2016 and higher than 2014, 2015 and 2017. This

Table 35. Mean mineral concentrations of chickpea cultivars grown in the USA, 2018.

	Year								µg/kg
Cultivar	**Ca**	**Cu**	**Fe**	**K**	**Mg**	**Mn**	**P**	**Zn**	**Se**
Bronic	789	7	46	8694	1245	40	3095	36	220
CDC Frontier	685	6	44	8389	1272	35	2864	32	299
CDC Orion	805	6	42	7942	1253	32	2530	26	308
Dylan**	948	7	51	8706	1293	52	2845	30	230
HB14**	739	8	55	9082	1295	41	3115	38	186
Marvel	699	7	44	8713	1327	33	3215	39	342
Nash**	808	7	44	9420	1306	37	3181	38	169
Sawyer	675	7	41	8706	1268	37	2920	32	263
Sierra	649	7	47	8576	1286	38	2884	34	245
Unknown	748	6	40	8222	1226	29	2515	29	266

*mineral key: calcium (Ca), copper (Cu), iron (Fe), potassium (K), magnesium (Mg), manganese (Mn), Phosphorus (P), Zinc (Zn) and selenium (Se);
** Value from only one sample.

Table 36. Physical parameters of chickpeas grown in the USA, 2013-2018.

	Year							
	2018		2017	2016	2015	2014*	2013	
Physical Parameter	**Range**	**Mean (SD)**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**5-year Mean (SD)**
Test Weight (lb/Bu)	57-65	62.0 (1.4)	61 (2)	61 (2)	60	61	61	61 (1)
1000 Seed Wt	195-591	410 (71)	421 (72)	410 (106)	404	403	387	411 (254
Water Hydration Capacity (%)	69-128	102 (10)	104 (13)	105 (15)	108	113	103	104 (3)
Unhydrated Seeds (%)	0-1	0 (2)	0 (1)	1 (1)	0	0	0	1 (2)
Swelling Capacity (%)	89-166	130 (14)	129 (27)	141 (12)	136	105	**	nd
Cooked Firmness (N/g)	17.7-44.6	27.9 (6.1)	26 (5)	22.0 (3.0)	19.7	**	**	nd

*2014 data is for Frontier cultivar only; **data not reported; nd = not determined.

indicates that the chickpeas from 2018 were slightly redder than the 2014, 2015 and 2017 samples, but slightly less red than the chickpea from 2013. The "b" value for chickpeas from 2018 indicated a less yellow color compared to the 2013 and 2015 chickpea samples, but yellower than the chickpea from other harvest years.

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 38) compared to pre-soaked chickpeas. This same trend occurred in samples from previous years except 2014. 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 2018 was larger than the color difference for samples from previous years except 2015 (Table 38). This suggests better color stability of the chickpeas from 2015.

Among cultivars, Dylan had the highest L* value (58.09) while CDC Orion had the lowest (i.e. 51.30). The Dylan cultivar also had the lowest yellowness value while the Marvel cultivar had the highest yellowness (Table 39). Visual observations support the color value differences as the Dylan cultivar appeared whiter in color than other cultivars. All cultivars underwent an increase in lightness during soaking, as evidenced by the higher L* value of the soaked sample. This observation was also noted in other chickpea surveys. The greatest color difference was observed in the Dylan cultivar (Table 39). The change in color observed in the Dylan cultivar was likely due to the significant increase in redness and yellowness during the soaking.

Pasting properties
(Tables 40-41)

Peak, hot and cold paste viscosities of chickpeas grown in 2018 were lower than the 5-year mean values (Table 40). The viscosity data indicated that the pasting properties of the 2018 chickpea crop were most similar to the chickpeas from 2015 and 2017. The peak time was comparable to the chickpea from other harvest years except 2012, which had a significantly longer peak time. The pasting temperature was slightly higher for the chickpeas from 2017 compared to chickpeas from 2014 and 2016, but was the same temperature as the chickpea samples from 2015 and 2017.

Peak, hot and cold paste viscosities of the Dylan chickpea cultivar were greatest among cultivars tested (Table 41). In contrast, the cultivar Marvel had the lowest peak, hot paste and cold paste viscosities. Pasting properties were similar among other cultivars tested. Pasting temperature was lowest (73.4 C) and highest (77.9 C) for HB-14 and Marvel cultivars, respectively.

Table 37. Mean physical properties of chickpea cultivars grown in the USA, 2018.

Cultivar	Test Weight (lb/Bu)	1000 Seed Wt	Water Hydration Capacity (%)	Unhydrated Seeds (%)	Swelling Capacity (%)	Cooked Firmness (N/g)
Bronic	63.0	344	115	0	135	31.5
CDC Frontier	62.9	342	103	0	134	29.8
CDC Orion	61.8	422	96	0	130	27.3
Dylan*	59.9	505	113	0	128	27.9
HB14*	61.4	463	104	0	137	24.8
Marvel	64.9	229	112	0	155	28.2
Nash*	62.6	538	118	0	150	36.2
Sawyer	62.1	421	103	0	126	26.6
Sierra	61.0	474	101	0	119	26.7
Unknown	62.6	360	101	0	136	26.4

* Value from only one sample.

Table 38. Color quality of chickpeas grown in the USA before and after soaking, 2013-2018.

	Mean (SD) Color Values											
	Before Soaking						After Soaking					
Color scale*	2018	2017	2016	2015	2014	2013	2018	2017	2016	2015	2014	2013
L (lightness)	9.06 (1.14)	8.55 (1.43)	7.83 (1.61)	5.55 (0.76)	11 (2)	6 (1)	11.35 (1.05)	10.85 (0.98)	11.44 (1.04)	6.97 (1.28)	7.01 (0.44)	13 (3)
a (red-green)	21.74 (1.67)	21.28 (1.99)	22.19 (2.55)	14.19 (0.45)	28 (4)	15 (1)	34.94 (2.20)	34.36 (2.41)	34.11 (2.31)	31.47 (7.70)	29.26 (0.91)	53 (7)
b (yellow-blue)	14.04 (2.46)	13.69 (1.96)	10.83 (6.02)	15.47 (3.10)	**	**	34.36 (2.41)	34.11 (2.31)	31.47 (7.70)	29.26 (0.91)	53 (7)	26 (2)
Color Difference	13.69 (1.96)	13.80 (1.78)	10.83 (6.02)	15.4	**	**						

*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.

**data not reported

Table 39. Mean color quality of chickpea cultivars grown in the USA, 2018.

Cultivar	Mean Color Values**						
	Before Soaking			After Soaking			Color Difference
	L	a	b	L	a	b	
Bronic	52.33	10.12	22.50	56.40	12.84	38.57	16.97
CDC Frontier	54.13	9.34	21.84	57.11	12.01	36.45	15.22
CDC Orion	51.30	9.59	22.58	55.55	11.75	34.84	13.54
Dylan*	58.09	5.76	16.18	59.11	9.96	33.25	17.61
HB14*	51.71	9.16	21.21	55.16	11.70	33.78	12.96
Marvel	56.04	10.20	24.49	60.02	11.18	35.70	12.04
Nash*	56.85	7.83	18.86	58.05	11.90	34.06	15.85
Sawyer	54.60	8.73	21.42	57.98	10.57	34.41	13.78
Sierra	55.62	7.73	20.13	56.84	10.17	32.96	12.95
Unknown	52.51	9.77	22.92	56.48	11.68	34.80	13.44

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

Table 40. Pasting characteristics of chickpeas grown in the USA, 2012-2018.

Starch Characteristic	Year*							5-year
	2018		2017	2016	2015	2014	2012	
	Range	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Peak Viscosity (RVU)	100-170	131 (15)	126 (15)	139 (23)	126 (15)	143 (7)	178 (15)	144 (20)
Hot Paste Viscosity (RVU)	97-154	125 (12)	124 (14)	134 (22)	124 (14)	138 (7)	156 (11)	136 (12)
Breakdown (RVU)	43-124	6 (6)	3 (2)	6 (4)	3 (2)	5 (1)	23 (11)	8 (8)
Cold Paste Viscosity (RVU)	140-255	187 (29)	185 (24)	214 (70)	185 (24)	210 (2)	292 (46)	212 (57)
Setback (RVU)	15-110	62 (20)	62 (13)	80 (43)	62 (13)	17 (2)	136 (40)	66 (50)
Peak Time (Minute)	4.73-7.00	6.06 (0.65)	6 (0)	6.04 (0.61)	6 (0)	6 (0)	9.9 (1)	8 (2)
Pasting Temperature (°C)	72.5-79.2	75.8 (1.9)	76 (2)	74.5 (1.3)	76 (2)	74 (3)	**	nd

*data not reported in 2013; **not previously determined; nd = not determined

Table 41. Mean pasting characteristics of Kabuli chickpea cultivars grown in the USA, 2018.

Cultivar	Peak Viscosity (RVU)	Hot Paste Viscosity (RVU)	Breakdown (RVU)	Cold Paste Viscosity (RVU)	Setback (RVU)	Peak Time (Min)	Pasting Temperature (°C)
Bronic	138.5	132	6	186	54	6.2	77.2
CDC Frontier	131.1	124	7	171	47	6.2	76.9
CDC Orion	134.6	125	10	193	68	5.5	74.1
Dylan*	147.1	145	3	255	110	5.7	75.8
HB14*	142.4	139	4	219	81	5.8	73.4
Marvel	116.4	113	3	156	43	7.0	77.9
Nash*	146.1	141	5	223	82	5.6	77.5
Sawyer	129.1	124	5	191	67	6.4	76.4
Sierra	124.4	121	3	182	61	6.5	76.4
Unknown	124.5	118	7	176	58	5.9	75.3

* Only one sample of cultivar tested

Canning Quality

Canning quality was completed only on pea and chickpea. Lentil 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 42). This value was slightly higher than the water hydration capacity of peas from the 2017 crop year. Unlike 2017, a difference in water hydration capacity between the green (193%) and yellow (227%) market classes was observed. In comparison, water hydration capacities of peas in the soak test were 106 and 102% for green and yellow peas, respectively. Water hydration capacities ranged from 106 to 310% for all peas. In green peas, Hampton had the lowest water hydration capacity at 164% while CDC Greenwater had the highest at 272%. In yellow cultivars, Gunner (179%) and Salamanca (180%) had the lowest water hydration capacities while the CDC Amarillo cultivar had the highest (282%) value. The results of the soak test did not directly translate into similar results in the canning water hydration in the context of an order. Although, the samples having the lowest soak test water hydration capacity tended to have the lowest water hydration capacities in the canning test. For example, Salamanca had the lowest water hydration in both the soak test (Table 11) and canning test (Table 43) while Icicle had the lowest water hydration capacity in the soak test the Hampton cultivar had the lowest water hydration capacity in the canning tests for the green cultivars. The Ewald cultivar had highest soak test water hydration capacity while CDC Amarillo had the highest (282%) water hydration capacity in the canning test. Ewald had an average water hydration capacity in the canning evaluation (Table 43).

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 177 to 260%, with a mean value of 214% (Table 42). The green pea cultivars Icicle and Shamrock had the lowest (185%) and highest (228%) swelling capacities, respectively. In yellow cultivars, Gunner had the lowest swelling capacity at 177% while CDC Leroy had the highest at 238%. Unlike water hydration, 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. The mean canned firmness value of all peas was 4.7 N/g (Table 42). In comparison, the mean cooked firmness for all peas was 21 N/g (Table 9). As expected, the canned peas were less firm than the cooked peas. The DCD Greenwater cultivar was the least firm while Hampton was the firmest (Table 43). These results coincide with the outcome of the water hydration capacity and less so for the swelling capacity outcomes. For example, CDC Greenwater had the highest water hydration capacity among green cultivars and the lowest firmness. This would be expected since more water retained by the peas would result in a softer texture.

The color of the dry pea changed after the canning process. The color difference fell between 6.10 and 19.98, with a mean value of 15.10 for all peas, and 18.16 and 13.30 for the green and yellow market classes, respectively. The color difference (Table 42) in the yellow peas was less than the color difference that resulted from soaking (Table 12).

A slightly higher color difference was observed in canned peas compared to soaked peas. The lightness decreased during canning for both green

Table 42. Mean physical and color parameters of canned dry peas grown in 2018.

Sample**	Hydration Capacity (%)	Swelling Capacity (%)	Canned Firmness (N/g)	Before Canning *			Post Canning*			Color Difference
				L	a	b	L	a	b	
All	214	214	4.7	56.13	3.63	17.33	52.86	5.02	30.96	15.10
Green	193	206	5.2	51.68	-1.92	14.15	46.02	2.38	30.58	18.16
Yellow	227	216	4.4	58.76	6.91	19.21	56.91	6.59	31.18	13.30

*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. **data includes all samples or is separated by pulse color; color difference = change in value before canning and after canning and yellow market classes. In the soak test, only the green cultivars darkened upon soaking. The greatest color difference was observed in the Icicle cultivar after canning (Table 43). The Hampton cultivar had the lowest color difference among the green cultivar after canning. In the yellow cultivars, Salamanca and Montech 4193 had the highest and lowest color differences, respectively (Table 43). The lowest color difference observed in the soak test was associated with the Mystique cultivar (Table 13). This cultivar had the second lowest color difference value in the canning test.

Chickpeas

The mean **water hydration capacity** of canned chickpea was 127% (Table 44). Like pea, water hydration capacity (102%) of chickpea during the soak test was less than canned chickpea water hydration capacity (127%). Water hydration capacities ranged from 96 to 147% for all chickpea. CDC Orion had the lowest water hydration capacity at 117% while Bronic and Dylan had the highest at 140%. In the soak test, CDC Orion also had the lowest water hydration capacity, which matched the outcome of the canning results. However, Bronic and Dylan did not have the highest water hydration capacities in the soak test, as was observed in the canning water hydration capacity (Table 43).

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 110 to 219%, with a mean value of 173% (Table 44). CDC Orion had the lowest mean swelling capacity at 155% while Nash had the highest at 219%.

Table 43. Mean physical and color parameters of canned dry pea cultivars grown in 2018.

Market Class	Cultivar	Hydration Capacity (%)	Swelling Capacity (%)	Canned Firmness (N/g)	Mean Color Values* Before Soaking L	a	b	After Soaking L	a	b	Color Difference
Green	Arcadia	203	218	5.4	53.77	-1.70	13.28	47.90	2.08	30.20	18.40
	Ariel	201	196	4.9	53.18	-2.15	12.90	46.07	2.55	30.93	19.96
	Banner	186	200	5.2	48.02	-2.65	15.01	42.93	2.86	30.84	17.68
	CDC Greenwater**	272	65	3.0	56.35	-1.27	11.79	48.80	1.05	29.93	19.79
	Ginny	188	208	5.7	52.65	-1.76	14.04	46.24	2.38	28.97	16.84
	Hampton**	164	187	7.4	52.26	-1.76	15.61	44.97	1.86	26.83	13.86
	Icicle**	178	185	6.2	54.06	-1.01	14.44	45.40	2.29	32.13	19.98
	Majorettes**	254	228	4.3	54.68	-1.41	12.60	52.98	1.33	30.93	18.73
	PRO 7123	199	192	4.6	49.00	-3.38	15.25	44.66	2.28	32.14	18.42
	Shamrock	169	231	5.1	46.01	-2.51	16.80	44.73	2.63	33.54	17.69
	Unknown	196	214	5.2	54.74	-1.16	13.04	47.60	2.30	30.01	18.90
Yellow	AAC Carver	261	214	3.8	58.43	7.91	19.64	58.70	6.87	34.72	15.35
	AC Earlystar	261	226	4.3	60.95	6.97	19.43	57.33	7.28	33.05	14.40
	Agassiz	210	192	3.9	60.42	6.12	17.41	57.10	6.27	27.46	11.49
	Bridger	221	226	3.6	58.12	6.89	19.18	57.28	7.14	30.88	12.66
	CDC Amarillo	282	228	3.1	58.33	7.97	20.58	55.93	6.88	29.84	8.69
	CDC Leroy**	220	238	4.0	57.14	5.63	18.88	56.36	6.63	33.15	14.35
	CDC Meadows	222	203	3.6	57.83	7.28	20.04	55.42	6.35	32.69	13.11
	DS Admiral**	197	220	5.0	58.14	7.08	18.88	56.66	7.50	31.31	12.53
	Ewald**	208	213	3.8	58.81	5.63	17.25	54.59	5.14	28.44	11.98
	Gunner**	179	177	6.2	56.89	9.81	21.66	56.06	7.09	29.95	8.85
	Korando	208	219	3.8	59.35	5.80	18.64	57.54	5.75	28.68	10.39
	Montech 4152**	211	215	4.3	60.44	5.79	18.34	58.41	5.15	30.53	12.38
	Montech 4193	208	217	3.7	53.11	6.14	18.92	57.77	7.65	30.79	17.11
	Mystique	262	208	3.2	59.38	7.79	19.65	58.34	6.78	25.49	7.96
	Nette	202	210	6.2	55.64	7.25	21.34	57.17	7.08	29.63	8.05
	Salamanca**	180	209	4.6	57.82	9.08	23.01	58.15	8.16	29.40	6.10
	Spider**	217	213	4.2	57.29	7.96	21.08	57.31	5.50	32.18	11.39
	Universal**	208	209	4.7	59.91	6.57	18.31	52.25	6.55	29.23	13.34
	Unknown	216	221	4.9	59.07	6.52	18.62	56.34	6.13	31.81	15.64

*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.

Table 44. Mean physical and color parameters of canned dry chickpea cultivars grown in 2018.

Cultivar	Hydration Capacity (%)	Swelling Capacity (%)	Canned Firmness (N/g)	Mean Color Values*						
				Before Soaking			After Soaking			Color Difference
				L	a	b	L	a	b	
All Chickpea	124	173	9.91	53.45	9.06	21.74	47.39	8.62	26.81	9.29
Bronic	140	195	8.06	52.33	10.12	22.50	46.59	9.76	29.39	9.26
CDC Frontier	123	165	10.09	54.13	9.34	21.84	47.31	8.49	26.25	8.77
CDC Orion	117	155	11.54	51.30	9.59	22.58	47.99	8.09	27.17	7.59
Dylan**	140	196	9.54	58.09	5.76	16.18	49.68	6.73	25.31	12.46
HB14**	128	188	8.88	51.71	9.16	21.21	41.96	8.74	24.93	10.63
Marvel	135	196	9.47	56.04	10.20	24.49	49.43	7.75	24.06	8.52
Nash**	137	219	8.91	56.85	7.83	18.86	47.09	9.59	25.19	11.84
Sawyer	123	188	9.04	54.60	8.73	21.42	47.55	8.05	26.23	8.73
Sierra	122	176	9.41	55.62	7.73	20.13	45.86	9.39	25.45	12.70
Unknown	122	157	10.25	52.51	9.77	22.92	50.44	8.26	28.50	6.97

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

The **canned firmness** values of chickpeas were significantly lower than the cooked firmness values of soaked chickpeas. The mean canned firmness value of all chickpeas was 9.9 N/g (Table 44). In comparison, the mean cooked firmness for all chickpeas was 27.9 N/g (Table 36). As expected, the canned chickpeas were less firm than the cooked chickpeas. The Bronic cultivar was the least firm while CDC Orion was the firmest (Table 44). These results coincide with the outcome of the water hydration capacity and the swelling capacity outcomes. For example, CDC Orion had the lowest swelling and water hydration capacities among cultivars and had the greatest firmness. This would be expected since the chickpea, resulting in a firmer texture, retains less water.

The color of the chickpeas changed after the canning process. The color difference fell between 6.97 and 12.70, with a mean value of 9.29 for all chickpeas (Table 44). A slightly lower color difference was observed in canned chickpeas compared to soaked chickpeas. The L* or lightness decreased during canning. In contrast, the L* value of chickpea increased in the soak test. The greatest color difference was observed in the Dylan cultivar after canning (Table 44). The substantial reduction in the L* value likely contributed the higher color difference value. The CDC Orion cultivar had the lowest color difference after canning.

Guide to Color Analysis

The color evaluation of the Shamrock cultivar after soaking. Color values include: L= 41.77, a= -5.92, b= 30.85.

The color evaluation of the Arcadia cultivar after soaking. Color values include: L= 47.17, a= -6.11, b= 25.29.

The color evaluation of the Gunner cultivar after soaking. Color values include: L= 61.15, a= 11.49, b= 35.33.

Percentage Recommended Daily Allowance

The percentage recommended daily allowance (%RDA) provides an indication of the nutrient concentration of a food item. Based on a 50 g (dry) serving for both adult males and females 19-50 years of age, US-grown field pea, lentil and chickpea can be considered good sources of selenium, iron, zinc, potassium, and magnesium (Table 45). The RDA provided by a 50 g serving of pulses from 2018 fall within the range of those reported in 2013-2017.

Table 45. Percent recommended daily allowance (RDA) of minerals in a 50 g (dry) serving of pulses based on 2018 data.

	%RDA in a 50 g of serving of pulses for adults (19-50 yrs)*								
	Se	Fe		Zn		Ca	Mg		K
Crop	Male/Female (55 µg)	Male (8 mg)	Female (18 mg)	Male (11 mg)	Female (8 mg)	Male/Female (1000 mg)	Male (410 mg)	Female (310 mg)	Male/Female (4.7 g)
Dry pea	19	29	13	12	16	3	13	18	8
Lentil	19	30	13	16	22	2	12	16	8
Chickpea	25	27	12	14	19	4	15	20	9

*%RDA and Adequate Intake were calculated based on www.nap.edu (Food and Nutrition Board, Institute of Medicine and National Academies; https://www.nal.usda.gov/fnic)

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