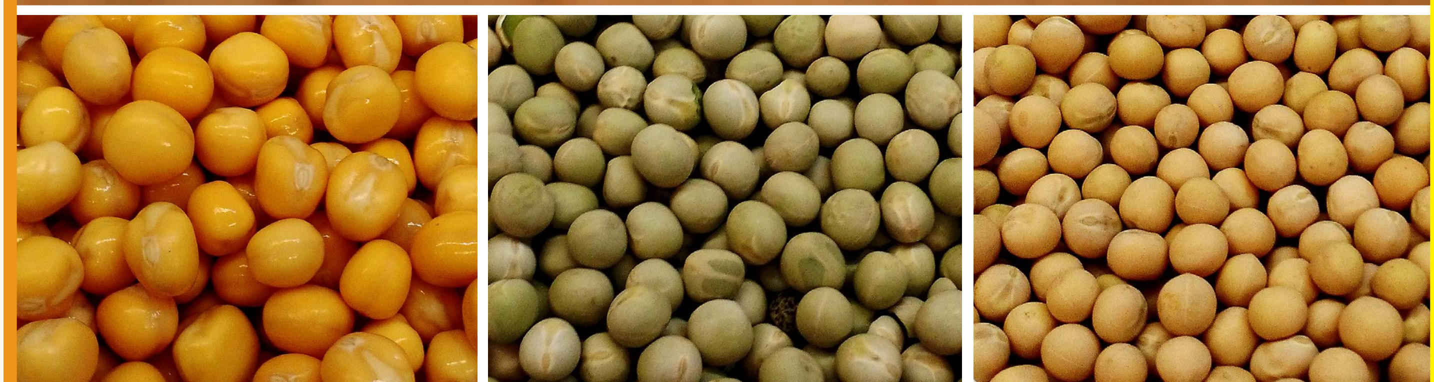

2017
U.S. Pulse Quality Survey

NDSU NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

Northern Pulse Growers Association

USA Dry Pea & Lentil Council

Contents

2017 Overview and Author's Comments

Summary Points

1. The 2017 pulse quality report represents the 10th variation of a pulse quality evaluation started by the Northern Crops Institute in 2008.
2. Data from approximately 190 samples received from major US pulse growing regions were evaluated.
3. Similar proximate composition to that of the 2016 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 first time in the survey history. Data supports the lowfat nature of peas and lentils.
5. A canning quality evaluation was included in this report for pea and chickpea.

This report provides a summary of the 2017 pulse crop quality for dry pea, lentil, and chickpea cultivars grown commercially in the USA. 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 first 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.

In 2017, a total of approximately 190 pulse samples were collected from the major US pulse growing regions. The seeds evaluated included 93 dry pea, 57 lentil and 37 chickpea, which were acquired from pulses growers and industry representatives in pulse growing areas in Idaho, Nebraska, Montana, North Dakota, South Dakota and Washington. According to the USDA National Agricultural Statistics Service, pulse harvested acreage and estimated total production was highest for the 2017 crop years compared to the 4 previous years. Lentil and chickpea production was up significantly. Modest gains in harvested pea acres was observed in 2017.

Results from the proximate (i.e., moisture, protein, etc.) composition analyses indicates that the peas and lentils were similar to the 2016 crop year. Chickpea proximate composition was most similar to the chickpea harvested in 2012 and 2016 crop years. Similar to previous years, the 2017 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 2017 came from the most diverse growing regions since the survey was started. In general, all pulses had lower moisture contents in 2017 compared pulses from 2016, and had moisture contents similar to their respective 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. No comparison could be made to previous crop years since 2017 was the first time the fat analysis was completed. The yellow and green dry pea composition was nearly identical to each other. Differences in proximate composition were observed between the three lentil market classes. Similar to results reported previously, the pulses grown in 2017 are an excellent source of a wide range of mineral including iron (Fe), zinc (Zn), magnesium (Mg) and selenium (Se). The 2017 pulses provide in excess of 10% of the RDA for these minerals. Regardless of market class, dry peas from 2017 had lower magnesium levels compared to 2015 and 2016, but higher than the previous four years (2012-2014). The calcium content of the peas from 2017 were higher than previous years while phosphorus was lower than previous crops. Potassium content was higher in peas from 2017 compared to 2015 and 2016. The other minerals fell within the range of the previous crop years, except selenium which was similar to the values obtained in 2016, but lower than values reported between 2012 and 2015. Similar trends in mineral composition of lentils and chickpeas was observed with only a few exceptions. Differences in mineral composition between lentil market classes were minimal. The major minerals composition in chickpeas from 2017 were comparable to the 2015 and 2016 crop years. However, trace minerals tended to be higher in 2017 than 2015 and 2016.

The physical parameters such as water hydration capacity, test weight, and color analysis of the 2017 had varying results compared to previous pulse crops. The test weight of dry peas, lentils and chickpeas were approximately that of the 5-year average. The 1000 seed weight was slightly higher for lentils and chickpeas, but slightly lower for peas when compared to the 5-year mean. The water hydration capacities of dry peas and lentils were higher than the 5-year average while chickpea water hydration capacities were similar to or slightly lower than the 5-year mean value. Swelling capacities of the lentils and peas were higher than values from 2014 and 2016 and the 5-year average, but lower than their respective samples compared to 2015. Swelling capacity was slightly lower for chickpea compared to the 5-year average.

The lightness (L*) color quality and color difference values of dry peas from 2017 were comparable to the peas from 2016, but were lower than L* values from other crop years. The lentil color quality from the 2017 crop tended to be similar to values observed in the 2016 crop year. The redness value in the red lentils was higher in the red lentils from previous crop years except 2016. Green lentils from 2017 had higher yellowness and lower greenness values than lentils from 2012-2015 crop years. The 2017 chickpea crop had lightness color values lower than previous crop years except 2016. However, the redness and yellowness values were similar to chickpeas grown in 2015 and 2016, which tended to be higher than chickpeas from 2012 and 2014.

The pasting characteristics of peas from 2017, in general, were comparable to the 5-year mean values. The peas from the yellow market class had viscosity properties that were similar to the yellow peas from 2014 and 2015 while the pasting characteristics of green peas from 2017 not closely aligned with pea from other crop years. The 2017 lentil crop had peak and hot paste viscosities that were similar to values reported in 2016. However, cold paste viscosity and set back values were higher than the 5-year mean values. The pasting characteristics of the green market class were closer to the 5-year mean viscosity values than the red market class. The viscosity values of Spanish Brown lentils were greater in 2017 compared to previous crop years. The 2017 chickpea crop had viscosity values that were comparable to the chickpea from 2014 and were lower than the 5-year mean viscosity values.

A canning evaluation was completed on peas and chickpeas. 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. 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 planted acreage in 2017 was 2,877,300 (USDA 2017; Table 1), which was approximately 300 thousand more acres than in 2016. Total US pulse production (Metric Tons (MT) in 2017 is estimated to be 1,301,324, which down from 1,927,285 from 2016. The drought conditions affecting the pulse growing regions likely contributed to the lower production in 2017 compared to the previous year. However, 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 resulting production was similar to the 2013 production (Table 1).

The UDSA (2017) estimated that the dry pea acreage was 1,154,500, which was down from 1,334,800 in 2016. However, the 2017 pulse acres were up from 1,083,500 acres in 2015, 924,278 acres in 2014 and 856,501 acres in 2013 (Table 1). Pea production (648,734 MT) in 2017 was lower than the previous four years (Table1). Lentil acreage was 1,104,000 in 2017, which is higher than the 917,000 acres in 2016, 476,000 in 2015 and 260,243 in 2014 (USDA; Table 1). Lentil production (339,381 MT) in 2017 was lower than the 564,087 MT in 2016, but higher than 276,225 MT in 2015, 151,248 MT in 2014, and 284,332 MT in 2013. Chickpea harvested acres (618,800) in 2017 was significantly higher than the 277,500 in 2016, 203,100 in 2015, 202,253 acres in 2014 and 208,243 acres in 2013 (USDA 2016). Production was approximately 313 thousand MT in 2017, which was substantially higher than the 135,016 MT in 2016, 98,817 MT in 2015, 127,386 MT in 2014 and 145,636 MT in 2013.

Table 1. United states pulses acreage and production summary for 2013-2017.

	2017		2016		2015		2014		2013	
Crop	**Acreage***	**Production****	**Acreage***	**Production****	**Acreage***	**Production****	**Acreage***	**Production****	**Acreage***	**Production****
Dry Peas	1,154,500	648,734	1,334,800	1,228,282	1,083,500	738,203	924,278	783,098	856,501	833,841
Lentil	1,104,000	339,381	917,000	564,087	476,000	276,225	265,703	151,248	366,908	284,332
Chickpea	618,800	313,209	277,500	135,016	203,100	98,817	202,253	127,386	208,243	145,636
Total	**2,877,300**	**1,301,324**	**2,529,300**	**1,927,385**	**1,762,600**	**1,113,245**	**1,392,234**	**1,061,732**	**1,431,652**	**1,263,809**

*Acreage = Acres Planted - USDA NASS (2017);**Production = Metric Tons - U.S.A. Dry Pea and Lentil Council / Northern Pulse Growers Association

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 was added as another nutrient analyzed in 2017 following the AOCS Method Ba 3-38 for total lipids. The second test added in 2017 was a canning quality evaluation. This evaluation serves as an 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. Data included in the canning quality was firmness, water hydration and swelling capacity and changes in color during canning and short storage.

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.
- 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.

Table 2. Quality attribute, analytical method, and remarks for analyses conducted for the 2017 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 chcloride 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 93 dry pea samples were collected from Idaho, Montana, Nebraska, North Dakota, Washington and Wyoming from August to October 2017. Growing location, number of samples, market class, and genotype details of these dry pea samples are provided in Table 3. The majority of the dry pea samples were received from North Dakota followed by Montana and Washington. Green peas accounted for 38 of the samples collected, where Aragorn (5), Banner (4), Ginny (4) and Greenwood (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 55 of the pea samples collected, where Nette (8), AAC Craver (4) Agassiz (4), and CDC Amarillo (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). However, many of the green and yellow pea samples were not identified.

Table 3. Description of dry pea samples used in the 2017 pulse quality survey.

State	No. of samples	Market class	Cultivars	
Idaho	3	Green	Banner	Greenwood
Montana	18	Green	Aragorn Banner	Ginny Greenwood
		Yellow	Hyline CDC Meadows	Trapeze
Nebraska	1	Yellow	CDC Amarillo	
North Dakota	55	Green	Arcadia CDC Striker Greenwood	Majoret Shamrock
		Yellow	AAC Carver AC Earlystar Agassiz CDC Amarillo CDC Leroy DS Admiral	Gambit Hyline Mystique Nette Salamanaca Spider
South Dakota	3	Yellow	AAC Carver AC Earlystar	Agassiz
Washington	12	Green	Aragorn Ariel Banner Columbian	Ginny Hampton Journey
		Yellow	Universal	
Wyoming	1	Green	Banner	

Proximate composition of dry pea (Tables 4-6)

Moisture

The moisture content of dry pea ranged from 7.0-12.3% in 2017 (Table 4). The mean moisture content of all 93 pea samples was 9.5%, which is higher than the 5-year mean of 9%. Dry peas grown in 2017 had moisture contents similar to pea samples from the 2012 and 2016 harvest years. The moisture content is lower than the 13% 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 yellow and green market classes were different by approximately 0.8 percentage points (Table 5). The green and yellow seed moisture of 9.0 and 9.8%, respectively, were approximately the same as the 5-year mean values of 9 and 10%, respectively. The highest moisture contents were observed in the Shamrock cultivar (i.e. green pea) and the Mystique cultivar in the yellow market class (Table 6). However, most of the peas had moisture contents between 8 and 10% and all pulses remained under the maximum moisture of 14%, which is necessary for storing pulses.

Table 4. Proximate composition of dry peas grown in the USA, 2012-2017.

Proximate Composition (%)*	2017		Mean					5-year
	Range	Mean (SD)	2016	2015	2014	2013	2012	Mean (SD)
Moisture	7.0-12.3	9.5 (1.1)	10	11	11	6	9	9 (2)
Ash	2.0-3.2	2.5 (0.2)	2.5	2.5	2.3	2.5	2.6	2.5 (0.1)
Fat	0.9-3.3	2.1 (0.7)	**	**	**	**	**	**
Protein	17.0-26.1	21.5 (1.8)	21	20	23	25	25	23 (2)
Total Starch	38.1-47.6	41.9 (2.0)	43	42	44	52	52	47 (5)

*Composition is on an "as is" basis; ** Data not previously reported

Table 5. Proximate composition of different market classes of dry peas grown in the USA, 2012-2017.

Proximate Composition (%)*	Mean (SD) of green pea						5-year Mean (SD)
	2017	2016	2015	2014	2013	2012	
Moisture	9.0 (1.1)	9.6 (1)	10 (1)	11 (1)	5 (3)	9 (0.7)	9 (2)
Ash	2.5 (0.2)	2.4 (0.2)	2.5 (0.2)	2.3 (0.2)	2.5 (0.1)	2.7 (0.2)	2.5 (0.1)
Fat	2.1 (0.7)	**	**	**	**	**	**
Protein	21.6 (2.0)	21.0 (2)	21 (2)	23 (1)	23 (3)	25 (3)	23 (2)
Total Starch	41.4 (2.1)	42.1 (3)	41 (3)	44 (2)	52 (7)	53 (6)	46 (6)
Starch Characteristics	**Mean (SD) of yellow pea**						**5-year Mean (SD)**
	2017	**2016**	**2015**	**2014**	**2013**	**2012**	
Moisture	9.8 (0.9)	10.5 (1)	11.5 (1)	12 (1)	7 (3)	9 (0.6)	10 (2)
Ash	2.5 (0.2)	2.6 (0.2)	2.4 (0.2)	2.4 (0.1)	2.4 (0.1)	2.6 (0.2)	2.5 (0.1)
Fat	2.2 (0.8)	**	**	**	**	**	**
Protein	21.4 (1.7)	20.6 (2)	19.9 (2)	22 (1)	23 (4)	25 (1)	22 (2)
Total Starch	42.2 (1.9)	43.3 (3)	41.2 (5)	43 (1)	52 (6)	50 (8)	46 (5)

*Composition is on an "as is" basis; **Data not previously reported

Table 6. Mean proximate composition of dry pea cultivars grown in the USA in 2017.

Market Class	Cultivar	Concentration (%)				
		Moisture	Ash	Fat	Protein	Starch
Green	Aragorn	8.3	2.6	2.8	20.6	42.7
	Arcadia**	8.7	2.2	1.5	21.2	44.2
	Ariel	8.4	2.7	1.9	22.2	41.8
	Banner	8.4	2.7	2.5	19.8	41.9
	CDC Striker	9.1	2.2	1.4	22.0	41.4
	Columbian**	7.6	2.6	2.9	23.2	41.1
	Ginny	8.8	2.6	2.5	22.9	40.9
	Greenwood	8.8	2.5	2.1	20.8	42.5
	Hampton**	8.3	2.6	1.8	23.1	42.1
	Journey **	8.1	2.8	2.7	21.8	41.2
	Majoret**	9.4	2.1	1.2	23.3	41.4
	Shamrock	9.7	2.6	1.6	23.9	39.0
	Unknown	9.9	2.5	1.8	21.7	40.6
Yellow	AAC Craver	10.2	2.5	2.1	20.8	42.0
	AC Earlystar	9.5	2.8	2.2	20.6	41.4
	Agassiz	10.0	2.7	1.5	22.3	40.1
	CDC Amarillo	9.7	2.5	2.3	21.9	43.8
	CDC Leroy	9.4	2.3	3.1	21.3	41.9
	CDC Meadow**	9.7	2.3	3.1	22.5	41.4
	DS Admiral**	10.9	2.2	1.8	21.5	39.7
	Gambit**	8.8	2.5	2.6	22.0	42.4
	Hyline	9.4	2.8	2.4	23.0	42.2
	Mystique	11.3	2.6	1.0	19.7	43.1
	Nette	10.1	2.4	1.7	22.0	42.2
	Salamanca**	9.9	2.6	1.1	20.0	40.9
	Spider	9.0	2.4	1.7	22.1	41.7
	Trapeze**	7.0	2.4	0.9	24.1	43.8
	Universal**	9.3	2.4	2.2	20.9	42.7
	Unknown	9.9	2.4	2.7	20.5	42.8

*Composition is on an "as is" basis; **Only one sample of cultivar tested

Ash

Ash content of dry pea ranged from 2.0-3.2%, with a mean of 2.5%. The mean ash content of dry peas grown in 2017 was identical to the 5-year mean (Table 4). 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 2.5%. Some variability in ash content was observed among cultivars (Table 6). Journey (2.8%) had the highest ash content among green peas while Majoret had the lowest (2.1%) ash content (Table 6). AC Earlystar, Ariel and Hyline cultivars of the yellow market class had the highest mineral content at 2.8%. DS Admiral had the lowest (2.2%) ash content among yellow peas.

Fat (Lipid)

Fat content of dry pea ranged from 0.9 to 3.3% with a mean of 2.1%. The mean fat content was not previously reported for the pulse survey. However, the data does agree with published reports of 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 Columbian (green) and CDC Leroy and CDC Meadow (yellow) had the highest fat contents in their respective market classes (Table 6). In contrast, Majoret (green) and Trapeze (yellow) had the lowest fat contents among their respective market classes.

Protein

Protein content of dry pea ranged from 17 to 26.1% with a mean of 21.5%. The mean protein content was comparable to the peas from the 2016 crop year, but lower than 2012-2014 crop years. The mean protein content of dry peas grown in 2017 was lower than the 5-year mean of 23%. The lower protein might be an artifact of the drought observed during the 2017 growing season.

The protein contents of the green and yellow market classes were approximately the same (Table 5). The green peas from 2017 had lower protein content compared to 5-year mean value (22% vs. 23%), but was similar to protein contents in peas from 2015 and 2016 crop years. Yellow peas had a mean protein content (21.4%), which was lower than the 5-year mean value of 22%. Shamrock (green) and Trapeze (yellow) cultivars had the highest protein contents in their respective market classes (Table 6). In contrast, Banner (green) and Mystique (yellow) had the lowest protein contents among their respective market classes.

Total starch

Total starch content of dry pea ranged from 38.1 to 47.6% with a mean of 41.9%. The mean total starch content of dry peas grown in 2017 was comparable to dry peas from the 2015 harvest year (i.e. 42%), but lower than the 5-year mean of 47%.

The starch contents of the green and yellow market classes were both approximately 41 and 42%, respectively (Table 5). Green peas had a mean starch content (41.4%) that was lower than the 5-year mean value of 46%. Although the 5-year mean value for the yellow peas was higher (46%) than the mean starch content (42.2%), the mean starch content of yellow peas harvested in 2017 was higher than the yellow peas obtained from the 2015 harvest year, but was comparable to starch contents in peas from the 2014 and 2016 harvest years. Arcadia had the highest (44.2%) starch content among the green peas while CDC Amarillo and Trapeze had the highest starch content in yellow peas. Shamrock (39%) and DS Admiral (39.7%) 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 2017. The mean calcium content for all pea samples was 616 mg/kg with a range in values of 372 to 840 mg/kg. Iron content ranged from 34 to 70 mg/kg with a mean value of 50 mg/kg. Selenium mean content was 212 mg/kg with a range in values of 103 to 472 µg/kg. The variability in mineral content is further illustrated by the range in potassium (5573 to 8228 mg/kg) and phosphorus (2004 to 3195 mg/kg) contents. The variability in minerals likely relates to the soil in which the pulse is grown. Samples evaluated were from different many growing regions and that may have impacted mineral composition. Potassium and phosphorus account for the highest amounts of minerals in the pea samples regardless of market class (Table 7). The potassium content of green peas from 2017 was higher than the potassium in green peas from 2015 and 2016 crop year, but lower than the 2012-2014 crop years. In contrast,

Table 7. Mineral concentrations of dry peas grown in the USA, 2012-2017.

Micronutrient (mg/kg)	Mean (SD) of green pea						5-year Mean
	2017	2016	2015	2014	2013	2012	
Calcium	597 (98)	552 (82)	534 (91)	554 (106)	333 (169)	345 (167)	464 (114)
Copper	7 (1)	6 (1)	5 (1)	6 (1)	6 (2)	*	nd
Iron	51 (7)	45 (6)	44 (7)	42 (6)	41 (14)	41 (9)	43 (2)
Magnesium	1059 (47)	1224 (106)	1280 (82)	813 (41)	689 (242)	440 (98)	889 (358)
Manganese	10 (2)	10 (2)	9 (1)	9(2)	11 (4)	*	nd
Phosphorus	2456 (251)	3792 (810)	3179 (404)	2583 (326)	2902 (1190)	3242 (283)	3140 (448)
Potassium	6946 (542)	5781 (448)	6709 (662)	8801 (715)	7529 (1801)	9004 (601)	7565 (1371)
Zinc	30 (6)	24 (4)	24 (4)	32 (7)	38 (6)	25 (4)	29 (6)
Selenium (µg/kg)	206 (62)	176 (29)	151 (49)	369 (65)	300 (300)	600 (500)	319 (181)

Micronutrient (mg/kg)	Mean (SD) of yellow pea						5-year Mean (SD)
	2017	2016	2015	2014	2013	2012	
Calcium	630 (90)	593 (87)	571 (114)	599 (119)	494 (173)	390 (99)	529 (88)
Copper	8 (2)	6 (1)	5 (1)	6 (1)	5 (2)	4 (2)	5 (1)
Iron	50 (7)	45 (7)	38 (5)	42 (7)	36 (13)	50 (10)	42 (6)
Magnesium	1116 (60)	1351 (88)	1319 (80)	817 (111)	728 (182)	579 (68)	959 (354)
Manganese	10 (1)	11 (2)	8 (2)	10 (2)	11 (3)	10 (3)	10 (1)
Phosphorus	2424 (273)	4695 (981)	2912 (307)	2522 (395)	2223 (869)	2860 (319)	3042 (965)
Potassium	6918 (550)	6441 (508)	6168 (594)	8056 (2271)	6335 (1477)	7490 (743)	6898 (829)
Zinc	31 (4)	24 (4)	21 (3)	32 (7)	29 (8)	35 (7)	28 96)
Selenium (µg/kg)	216 (38)	197 (31)	200 (47)	365 (125)	500 (300)	500 (300)	352 (151)

*data not reported; nd= not determined

yellow peas from 2017 had mean potassium levels higher than previous crop years except 2012 and 2014. In general, Phosphorus content in both green and yellow peas was lower than samples from the five previous years. Calcium was higher in peas grown in 2017 compared to the previous years for both green and yellow peas (Table 7). Magnesium composition in both green and yellow peas from 2017 was lower in pea samples from 2015 and 2016, but higher than the magnesium contents in peas from 2012-2014 harvest years. The trace mineral (copper, iron, manganese and zinc) content of peas harvested in 2017 tended to be higher than those of the previous 5 harvest years (Table 7). Iron content was higher in both green and yellow peas compared to the 5-year mean values. Manganese tended to be similar to previous years (Table 7). Zinc contents in both green and yellow peas were higher than the 5-year mean value and zinc contents in peas from 2013, 2015 and 2016. Mean selenium (another trace mineral) contents of green and yellow peas grown in 2017 were lower than values from peas grown in 2012-2014, but were higher than selenium contents in peas from other crop 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 501 mg/kg in Majoret to 747 mg/kg in Hampton while the calcium content varied from 540 mg/kg to 770 mg/kg in Trapeze and DS Admiral yellow pea cultivars, respectively. Potassium content in Journey and Hyline were highest (7975 and 7396 mg/kg) among the green and yellow pea cultivars, respectively, while Majoret and DS Admiral had the lowest (6094 and 5661 mg/kg) potassium contents among green and yellow pea cultivars, respectively. Majoret also contained the lowest potassium level in the 2016 pea survey. 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.

Table 8. Mean mineral concentrations of dry pea cultivars grown in the USA in 2017.

Market Class	Cultivar	Concentration (mg/kg)*								(µg/kg)
		Ca	Cu	Fe	K	Mg	Mn	P	Zn	Se
Green	Aragorn	614	6	44	7314	1030	10.3	2635	31	194
	Arcadia**	507	10	50	6913	1077	8.4	2216	26	223
	Ariel	624	6	53	7655	1061	10.6	2121	29	141
	Banner	522	7	52	7093	1071	10.4	2399	25	194
	CDC Striker	534	10	56	6447	1013	8.3	2172	38	246
	Columbian**	603	6	58	7037	1105	12.9	2329	24	160
	Ginny	591	7	48	7090	1071	10.6	2588	32	229
	Greenwood	701	8	54	6783	1096	10.3	2534	34	202
	Hampton**	747	7	50	6930	1077	11.9	2499	33	164
	Journey**	511	7	60	7975	1034	12.8	2643	36	153
	Majoret**	501	10	57	6094	1016	8.5	2132	37	211
	Shamrock	521	9	56	7418	1004	7.6	2694	31	235
	Unknown	628	7	51	6690	1071	10.2	2400	26	211
Yellow	AAC Craver	664	9	44	6542	1120	10.7	2327	30	221
	AC Earlystar	587	10	45	7367	1130	9.9	2671	36	204
	Agassiz	585	10	52	7002	1074	9.2	2470	31	262
	CDC Amarillo	597	10	50	6428	1078	10.7	2507	31	227
	CDC Leroy	621	7	59	6808	1065	9.5	2260	31	217
	CDC Meadow**	690	7	55	7068	1120	10.0	2507	34	109
	DS Admiral**	770	9	70	5661	1214	10.8	2486	26	215
	Gambit**	688	7	50	6743	1156	12.2	2537	28	171
	Hyline	596	9	46	7396	1170	10.8	2664	28	224
	Mystique	599	9	52	7216	1132	9.5	2452	26	187
	Nette	608	8	52	6922	1126	10.3	2296	32	207
	Salamanca**	694	10	46	7162	1125	11.3	2581	34	233
	Spider	662	10	45	7127	1092	9.6	2168	29	240
	Trapeze**	540	10	44	7001	1117	8.9	2319	32	257
	Universal**	573	6	47	6635	1055	10.9	2503	29	154
	Unknown	643	7	48	6919	1121	9.6	2394	33	222

*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 67 lbs/bu with a mean of 63 lbs/bu. This mean value was the same as the 5-year mean of 63 lbs/bu (Table 9). The test weight for all pea samples harvested in 2017 was comparable to those from 2013 to 2016. The test weights of peas in the green and yellow market classes were the same (63 lb/bu). The test weight of individual cultivars were comparable to one another and fell within the range of 61 to 65 lb/bu (Table 11). DS Admiral had the highest (65 lb/bu) while the lowest was 61 lb/bu for the Columbian, Gambit and Universal Cultivars.

The range and mean **1000 seed weight** of dry peas grown in 2017 were 119-268 g and 204 g, respectively (Table 9). The mean value (204 g) 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 2012 harvest year. Furthermore, peas from 2017 had a mean 1000 seed weight value that was lower than the 5-year mean of 217 g. Peas of the green market class had a mean 1000 seed weight of 190 g, which is lower than the 5-year mean value of 218 g (Table 10). Peas of the yellow market class had a mean 1000 seed weight of 214 g, which is lower than the 5-year mean (222 g) and the 1000 mean weights of the peas 2013, 2015 and 2016 (Table 10). The individual cultivars (Table 11) varied extensively in 1000 seed weight, where the cultivars in the green market class varied (148 to 229 g) slightly less than cultivars in the yellow market class (166 to 264 g). Journey and Hampton and Trapeze and Gambit 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 measure hydration properties by mea-

Table 9. Physical parameters of dry peas grown in the USA, 2012-2017.

Physical Parameter	2017 Range	2017 Mean (SD)	2016 Mean	2015 Mean	2014 Mean	2013 Mean	2012 Mean	5-year Mean
Test Weight (lb/bu)	59-67	63 (2)	63	64	63	64	61	63 (1)
1000 Seed Wt (g)	119-268	204 (32)	224	215	216	222	206	217 (7)
Water Hydration Capacity (%)	86-219	104 (14)	97	111	102	98	103	102 (6)
Unhydrated Seeds (%)	0-7	2 (2)	2	2	2	8	0.8	3 (3)
Swelling Capacity (%)	126-184	148 (10)	137	145	152	*	*	nd
Cooked Firmness (N/g)	13.6-37.7	24 (6)	23	21	*	*	*	nd

*data not reported previously; nd = not determined

Table 10. Physical parameters of different market classes of dry peas grown in the USA, 2012-2017.

Physical Parameter	Mean (SD) of green pea 2017	2016	2015	2014	2013	2012	5-year Mean (SD)
Test Weight (lb/bu)	63 (2)	63 (6)	63 (2)	63 (2)	63 (2)	62 (1)	63 (1)
1000 Seed Wt (g)	190 (28)	213 (29)	207 (43)	219 (21)	212 (29)	201 (31)	218 (10)
Water Hydration Capacity (%)	107 (20)	100 (6)	114 (11)	100 (6)	102 (14)	104 (5)	101 (6)
Unhydrated Seeds (%)	2 (2)	1 (1)	2 (2)	1.0 (1)	8 (9)	1 (1)	3 (3)
Swelling Capacity (%)	146 (11)	140 (16)	142 (23)	150 (13)	*	*	nd
Cooked Firmness (N/g)	22 (5)	23 (5)	17 (5)	*	*	*	nd

Physical Parameter	Mean (SD) of yellow pea 2017	2016	2015	2014	2013	2012	5-year Mean (SD)
Test Weight (lb/bu)	63 (1)	63 (2)	64 (1)	62 (2)	64 (2)	62 (2)	63 (1)
1000 Seed Wt (g)	214 (30)	231 (27)	220 (32)	211 (38)	235 (29)	212 (23)	222 (11)
Water Hydration Capacity (%)	102 (5)	95 (6)	110 (18)	99 (13)	94 (11)	102 (8)	100 (6)
Unhydrated Seeds (%)	1 (1)	2 (4)	2 (2)	2.0 (2)	8 (9)	2 (3)	3 (3)
Swelling Capacity (%)	150 (9)	135 (16)	147 (14)	149 (13)	*	*	nd
Cooked Firmness (N/g)	25 (6)	22 (5)	22 (6)	*	*	*	nd

*data not reported previously; nd = not determined suring water hydration capacity, percentage of unhydrated seeds and swelling capacity. **Water hydration capacity** of dry peas ranged from 86 to 219%, with a mean of 104% (Table 9). The 2017 mean value is slightly higher than the 5-year mean of 102%. Peas from individual harvest years had slightly lower hydration capacity compared to 2017, except for the peas evaluated in 2015. The mean water hydration capacity in the green market class was five 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 2017 had hydration capacities similar to the peas from the 2012 harvest year and slightly higher values compared to peas from 2013, 2014 and 2016. In the green market class, Majoret and CDC Striker had the lowest (92) and highest (135%) water hydration capacities, respectively. The water hydration capacity ranged from 94% in AAC Craver (yellow) to 109% in Trapeze (yellow) cultivars (Table 11).

Unhydrated seed percentage ranged from 0-7% with a mean of 2%, which was comparable to the 5-year mean of 3% (Table 9). Peas from the green market class had unhydrated seed values of 2% while samples in the yellow market class had unhydrated seed values of 1% (Table 10). However, both market classes had fewer unhydrated seeds in 2017 compared to the 5-year mean and values from 2013 (Table 10). The majority of the green pea cultivars had unhydrated seed rates of 0 or 1% while Majoret had unhydrated seed rate of 7 % (Table 11). Gambit and Nette had unhydrated seed rates of 3%. 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 126 to 184% with a mean value of 148% (Table 9). The mean swelling capacity for peas from the 2017 harvest was slightly lower than peas from the 2014 harvest year. The swelling capacity of green peas was about 4 percentage points lower than the yellow pea market classes (Table 10), which is the opposite of that ob-

Table 11. Mean physical parameters of USA dry pea cultivars grown in 2017.

Market Class	Cultivar	Test Weight (lb/bu)	1000 Seed Wt (g)	Water Hydration Capacity (%)	Unhydrated Seeds (%)	Swelling Capacity (%)	Cooked Firmness (N/g)
Green	Aragorn	64	201	104	0	146	21.1
	Arcadia**	63	186	107	0	149	26.7
	Ariel	62	177	104	0	134	18.5
	Banner	64	172	135	1	149	20.0
	CDC Striker	64	203	100	1	140	27.6
	Columbian**	61	197	109	0	146	23.5
	Ginny	62	176	109	0	148	20.6
	Greenwood	64	186	101	1	148	23.9
	Hampton**	62	229	94	1	142	22.8
	Journey**	62	148	118	1	144	15.0
	Majoret**	63	225	92	7	140	28.3
	Shamrock	62	180	110	0	155	18.7
	Unknown	62	195	101	2	144	22.9
Yellow	AAC Craver	64	234	94	1	145	26.9
	AC Earlystar	63	215	101	0	145	20.6
	Agassiz	62	223	104	0	154	19.1
	CDC Amarillo	64	217	101	1	145	23.6
	CDC Leroy	63	192	108	0	151	26.0
	CDC Meadow**	64	178	102	1	139	19.3
	DS Admiral**	65	255	100	1	164	22.4
	Gambit**	61	264	100	3	133	24.5
	Hyline	63	211	105	0	154	19.2
	Mystique	63	258	96	1	156	27.8
	Nette	64	207	100	3	152	26.4
	Salamanca**	63	225	103	1	159	21.8
	Spider	62	218	100	1	146	29.7
	Trapeze**	64	166	109	1	160	21.2
	Universal**	61	220	101	0	131	22.1
	Unknown	64	207	104	1	152	27.9

**Only one sample of cultivar tested

served in 2016. Variability in the swelling capacity among cultivar was observed (Table 11). Shamrock (green) and DS Admiral (yellow) had the greatest swelling capacity while Ariel (green) and Universal (yellow) had the lowest swelling capacity among the cultivars tested (Table 11). The 2017 swelling capacities for the Shamrock and Universal cultivars followed the same trend as in 2016.

The **cooked firmness** values of peas were slightly higher than the two previous evaluations. The cooked firmness for all peas ranged from 13.6 to 37.7 N/g with a mean value of 24 N/g (Table 9). The cooked firmness of peas was slightly different between market classes (Table 10). The green peas had firmness values that were comparable to those values from 2016, but five percentage points higher than those from the 2015 green peas. The cooked firmness values in yellow peas were three percentage point higher than values obtained in 2015 and 2016. Among the green cultivars, Journey had the lowest cooking firmness (15 N/g) while Majoret (28.3 N/g) was the firmest (Table 11). For yellow cultivars, Spider had the highest (29.7 N/g) cooking firmness (i.e. most firm) among the cultivars tested while Agassiz (19.1 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 lower L* values than any other crop year since 2012, except 2016 where a comparable L* value was measured (Table 12). This observation was true for both green and yellow peas, although L* values were slightly higher in yellow pea in 2017 compared to 2016. This data indicates that the peas from the 2017 crop year were darker in color than those from previous years except in peas from the 2016 crop year. The less negative value for red-green (i.e., "a" value) value in 2017 indicates a less green color than 2012-2015 samples, but slightly more green than peas from 2016. The "b" value for green peas from 2017 was similar to peas from 2015 and indicates a less blue color compared to the peas from 2012-2014 and 2016 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 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 2017 appear light green in color compared to those from 2012 and 2014. For the yellow pea market class, the 2017 crop had similar lightness values to peas from 2016, but were slightly darker than the peas from the 2012 and 2014 crop years, but were darker than peas from 2013 and 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 peas in 2017 had "a" values that were similar to "a" values in peas from the 2013, 2015 and 2016 crops, but redder in color to the peas from 2012 and 2014. The same trends as the "a" values were observed for the "b" values for yellow peas. 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 2017 appear light yellow compared to peas from 2012 and 2014. However, the peas from 2017 would be similar in appearance to the peas from 2013, 2015 and 2016.

The color of the dry peas changed after the soaking process. The change in color was greater for peas from the 2017

Table 12. Color quality of dry peas grown in the USA before and after soaking, 2012-2017.

	Mean (SD) of green pea											
	Before soaking						After soaking					
Color Scale*	2017	2016	2015	2014	2013	2012	2017	2016	2015	2014	2013	2012
L (lightness)	52.69 (2.82)	52.01 (2.47)	62.32 (4.11)	61.99 (2.19)	66 (8)	60 (2)	47.52 (3.22)	46.86 (2.68)	57.83 (4.27)	55.12 (2.58)	59 (9)	54 (2)
a (red-green)	-1.24 (1.15)	-0.98 0.86	-3.53 (1.48)	-2.10 (0.89)	-3.8 (1)	-1.9 (1)	-5.24 (1.91)	-5.14 (1.18)	-9.07 (3.87)	-7.95 (2.56)	-15 (4)	-8.4 (1)
b (yellow-blue)	15.11 (1.51)	14.01 (1.26)	15.31 (1.52)	8.79 (0.84)	14 (2)	9 (1)	28.63 (2.74)	27.39 (1.82)	22.57 (6.28)	18.73 (2.56)	34 (4)	18 (1)
Color Difference	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	2017	2016	2015	2014	2013	2012	2017	2016	2015	2014	2013	2012
L (lightness)	58.73 (1.70)	57.29 (2.52)	71.33 (1.87)	65.83 (0.98)	71 (8)	65 (2)	60.56 (2.19)	69.51 (1.71)	68.00 (3.78)	64.76 (1.47)	77 (14)	65 (1)
a (red-green)	6.84 (1.34)	7.16 (0.84)	6.51 (0.79)	4.64 (0.43)	7.0 (1)	4.7 (1)	9.60 (2.38)	9.62 (0.90)	4.65 (1.73)	4.57 (0.33)	6.3 (5)	5.4 (1)
b (yellow-blue)	20.40 (1.92)	19.35 (1.37)	21.99 (2.23)	13.51 (1.20)	21 (2)	14 (1)	38.25 (4.44)	36.70 (2.55)	27.56 (5.19)	26.50 (3.36)	47 (6)	30 (1)
Color Difference	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 previously; color difference = change in value before soaking and after soaking

crop year compared to 2014 and 2015 (Table 12), but comparable to the peas from 2016. 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 2012-2016 crop years. In 2017, lightness increased after soaking of the yellow peas. 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 2017 were greater than those previously reported for green peas, but similar or greater than color differences in yellow peas from 2014 and 2015.

The Journey cultivar from 2017 had the lowest L* value, the lowest "a" value and the second highest "b" value, which produced an intense green color. CDC Striker had the highest L* and "a" values resulting in a light green colored pea. This pea was visually different from the Journey, Shamrock and Greenwood cultivars, which had blue green appearances. 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. The cultivars of the yellow

Table 13. Color quality of USA dry pea cultivars before and after soaking, 2017.

Market Class	Cultivar	Mean Color Values*						Color Difference
		Before Soaking			After Soaking			
		L	a	b	L	a	b	
Green	Aragorn	54.10	-1.62	14.30	47.62	-5.57	27.03	14.96
	Arcadia**	55.49	-1.50	15.25	47.84	-6.96	29.99	17.48
	Ariel	53.01	-1.60	12.31	46.11	-6.24	29.29	19.05
	Banner	47.33	-1.94	15.53	43.51	-6.37	30.88	16.65
	CDC Striker	57.03	0.28	15.51	53.10	-2.29	29.63	15.46
	Columbian**	50.98	-1.13	16.27	43.50	-7.76	31.55	18.28
	Ginny	54.02	-1.76	14.89	48.37	-5.12	28.13	14.93
	Greenwood	50.80	-1.96	14.79	46.70	-6.00	30.12	16.60
	Hampton**	54.93	-1.52	15.76	46.31	-6.03	29.21	16.77
	Journey**	49.00	-2.68	16.72	44.51	-7.59	31.15	15.94
	Majoret**	54.02	-0.68	13.79	52.23	-4.80	27.55	14.48
	Shamrock	50.70	-0.50	18.72	44.34	-5.02	32.19	15.90
	Unknown	53.57	-0.56	14.74	49.02	-4.22	26.59	13.78
Yellow	AAC Craver	59.50	7.92	21.05	59.82	12.54	42.02	21.62
	AC Earlystar	61.20	6.55	19.49	61.25	10.30	41.19	22.06
	Agassiz	59.92	6.52	18.64	60.90	9.91	39.28	21.04
	CDC Amarillo	59.10	7.62	20.42	60.52	10.38	39.81	19.70
	CDC Leroy	58.06	6.12	20.78	62.18	8.58	35.82	15.84
	CDC Meadow**	57.32	7.11	22.52	61.75	9.72	38.34	16.64
	DS Admiral**	57.81	7.77	18.68	60.45	9.84	38.89	20.50
	Gambit**	58.08	6.34	18.70	60.57	9.26	32.91	14.72
	Hyline	58.82	6.67	19.78	59.61	10.85	38.67	19.42
	Mystique	58.74	8.21	21.89	61.95	8.91	35.30	14.00
	Nette	57.81	7.48	22.18	60.50	9.54	35.96	16.55
	Salamanca**	57.93	6.63	20.04	61.40	9.28	37.49	18.00
	Spider	57.00	6.21	19.00	59.05	9.58	35.27	16.76
	Trapeze**	59.82	6.43	21.32	60.99	10.24	46.13	25.14
	Universal**	59.49	6.46	19.63	59.17	10.18	36.68	17.46
	Unknown	59.10	6.72	20.62	61.32	9.40	38.95	18.75

*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

peas had L* values between 52.15 and 70.00, with AC Earlystar being the lightest and Spider the darkest. Spider retained the darkest color after soaking while CDC Leroy became the lightest. Mystique had the highest redness ("a" value) score while the lowest was observed for the CDC Leroy cultivar (Table 13). After soaking, Mystique and AAC Craver had the lowest and highest redness scores, respectively. The yellowness of the dry yellow peas was greatest for CDC Meadow and lowest for Agassiz. After soaking, Trapeze had the highest yellowness values while Gambit had the lowest. The greatest color difference was observed in the Trapeze cultivar. The increase in yellowness during soaking likely contributed to the greatest color difference. Mystique had the least color change during soaking.

Pasting Properties
(Tables 14-16)

The peas from 2017 had peak viscosity, hot and cold paste viscosities and setback values that were most similar to peas from 2015 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. Pasting temperature ranged from 74 to 83 °C, with a mean of 76°C. The mean value is comparable to peas from previous years. The pasting characteristics were similar between the green and yellow pea market classes. Pea flour peak viscosities of 137 and 140 RVU were recorded for the green and yellow market classes, respectively (Table 15). Green peas

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

Starch Characteristic	2017		2016	2015	2014	2013	2012	5-year
	Range	Mean (SD)	Mean	Mean	Mean	Mean	Mean	Mean (SD)
Peak Viscosity (RVU)	112-176	139 (12)	146	136	143	141	123	138 (9)
Hot Paste Viscosity (RVU)	109-151	129 (10)	132	127	133	122	117	126 7
Breakdown (RVU)	1-35	10 (5)	14	8	10	20	6	12 (6)
Cold Paste Viscosity (RVU)	167-308	232 (31)	251	229	248	212	213	231 (19)
Setback (RVU)	55-174	103 (23)	119	102	115	91	96	105 (12)
Peak Time (Minute)	5-6	5 (1)	5	5	6	8	9	7 (2)
Pasting Temperature (°C)	74-83	76 (3)	76	77	78	*	*	*

*data not reported

Table 15. Starch characteristic of different market classes of dry peas grown in the USA, 2012-2017.

Starch Characteristic	Mean (SD) of green pea						5-year
	2017	2016	2015	2014	2013	2012	Mean (SD)
Peak Viscosity (RVU)	137 (12)	147 (23)	129 (19)	144 (25)	146 (17)	120 (12)	137 (12)
Hot Paste Viscosity (RVU)	127 (10)	131 (18)	122 (17)	135 (20)	122 (9)	115 (10)	125 (8)
Breakdown (RVU)	10 (5)	15 (9)	6 (5)	9 (7)	24 (15)	5 (5)	12 (8)
Cold Paste Viscosity (RVU)	231 (34)	253 (58)	219 (41)	252 (43)	218 (27)	215 (31)	231 (19)
Setback (RVU)	104 (25)	122 (43)	97 (25)	118 (26)	96 (23)	100 (22)	107 (12)
Peak Time (Minute)	5 (1)	5 (1)	6 (1)	6 (1)	8 (0.3)	9 (2)	7 (2)
Pasting Temperature (°C)	78 (2)	76 (2)	78 (2)	78 (1)	*	*	nd

Starch Characteristic	Mean (SD) of yellow pea						5-year
	2017	2016	2015	2014	2013	2012	Mean (SD)
Peak Viscosity (RVU)	140 (12)	145 (27)	140 (19)	140 (26)	136 (19)	126 (17)	137 (7)
Hot Paste Viscosity (RVU)	130 (10)	132 (19)	130 (15)	128 (18)	122 (19)	119 (11)	126 (5)
Breakdown (RVU)	10 (5)	13 (10)	10 (5)	12 (10)	17 (11)	8 (8)	12 (3)
Cold Paste Viscosity (RVU)	233 (28)	249 (60)	234 (39)	237 (45)	207 (42)	211 (38)	228 (18)
Setback (RVU)	103 (20)	117 (44)	104 (26)	108 (30)	85 (26)	93 (28)	101 (13)
Peak Time (Minute)	5 (1)	5 (1)	5 (1)	6 (1)	8 (0)	9 (1)	7 (2)
Pasting Temperature (°C)	78 (2)	75 (4)	76 (4)	77 (2)	*	*	nd

*data not reported; nd = not determined

from 2016 had higher peak viscosities than the peas from other harvest years, including peas from 2017. Hot and cold paste viscosities of green peas from 2017 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 2014 and 2015. Slightly lower pasting values were observed in 2017 compared to peas from 2016. The pasting values tended to be higher than peas from 2012 and 2013.

Within each market class, variability in starch characteristics was observed among cultivars. In the green market class, the Arcadia cultivar had the highest peak, hot paste and cold paste viscosities (Table 16). In contrast, Hampton had the lowest peak, hot paste and cold paste viscosities. The breakdown of starch during heating was greatest in Arcadia and least in Shamrock. The highest and lowest peak and cold paste viscosities of the peas in the yellow market class were observed in the Nette and DS Admiral cultivars, respectively (Table 16). CDC Amarillo and Universal had the lowest hot paste viscosity among yellow cultivars while Hyline had the highest hot paste viscosity. The breakdown of the paste during heating was greatest in Nette and least for DS Admiral. 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 3 to 16 RVU, which represents little breakdown of the starch paste.

Table 16. Mean starch characteristics of dry pea cultivars grown in the USA in 2017.

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	Aragorn	140	132	8	267	135	5.28	77.6
	Arcadia**	160	142	18	279	138	5.07	79.1
	Ariel	150	139	12	264	125	5.23	77.9
	Banner	131	119	12	205	86	5.25	79.1
	CDC Striker	148	134	14	254	120	5.13	78.4
	Columbian**	124	114	10	188	74	5.27	78.3
	Ginny	129	120	9	212	92	5.38	79.5
	Greenwood	141	134	6	254	120	5.30	77.3
	Hampton**	116	111	5	182	71	5.40	79.8
	Journey**	122	114	8	191	77	5.40	82.5
	Majoret**	131	123	7	217	94	5.13	77.6
	Shamrock	132	128	4	206	78	5.43	79.9
	Unknown	139	128	11	228	100	5.25	77.8
Yellow	AAC Craver	135	125	10	224	99	5.25	77.7
	AC Earlystar	136	130	6	222	92	5.37	78.3
	Agassiz	133	126	7	227	101	5.42	79.4
	CDC Amarillo	131	119	12	209	90	5.20	77.8
	CDC Leroy	146	132	14	229	97	5.17	79.1
	CDC Meadow**	131	127	5	226	99	5.40	78.4
	DS Admiral**	126	122	4	206	84	5.13	75.1
	Gambit**	143	133	10	243	111	5.07	75.1
	Hyline	148	140	8	242	102	5.36	77.5
	Mystique	139	127	12	239	113	5.00	74.7
	Nette	153	137	16	250	113	5.14	77.3
	Salamanca**	131	125	5	232	107	5.27	78.3
	Spider	138	128	10	220	93	5.17	77.5
	Trapeze**	132	126	6	211	85	5.27	79.0
	Universal**	129	119	11	219	100	5.13	75.9
	Unknown	141	132	9	239	107	5.27	78.2

*Value for only one sample.

Lentil Quality

Sample distribution

A total of 57 lentil samples were collected from Idaho, Montana, North Dakota and Washington between August and October 2017. Growing location, number of samples, market class, and genotype details of these lentil samples are provided in Table 17. Pardina represented all of the brown lentil while 26 of the 37 green lentils were the CDC Richlea cultivar. CDC Maxim (4) was the most common red lentil evaluated in the survey.

Table 17. Description of lentils used in the 2017 pulse quality survey.

State	No. of Samples	Market class	Cultivars
Idaho	5	Green	Merrit
		Red	Morton
		Spanish Brown	Pardian
Montana	12	Green	Avondale
			CDC Richlea
			CDC Viceroy
		Red	CDC Maxim
			CDC Redcoat
		Spanish Brown	Pardina
North Dakota	30	Green	CDC Meteor
			CDC Richlea
			Eston
		Red	CDC Maxim
Washington	10	Green	Brewer CDC Righlea Merrit
		Red	CDC Redcliff
		Spanish Brown	Pardina

Proximate composition of lentils (Tables 18-20)

Moisture

The moisture content of lentils ranged from 7.0 to 10.7% in 2017 (Table 18). The mean moisture content (8.8%) was higher than the 5-year mean of 8.6% and was similar to the mean value of lentils from 2016, but lower than lentils from 2014 and 2015. Overall, all samples evaluated had moisture contents below the 13-14% recommended for general storability.

The moisture contents of the different market classes were between 8.2 and 9.0% (Table 19). The green lentils had a mean moisture content of 9.0% while red and Spanish brown lentils had moisture contents of 8.6 and 8.3%, respectively. The green lentils from 2017 had lower moisture contents than the five previous years except 2013, but was identical to the 5-year mean moisture content. The 2017 red lentils had moisture contents higher than lentils from 2012, 2013 and the 5-year mean, but lower than the lentils from 2014-2016. Spanish brown lentils had a mean moisture content that was slightly higher than the lentils from 2016, but lower than lentils from 2014 and 2015. The highest moisture contents were observed in the Avondale (9.3%), CDC Meteor (9.3%) and CDC Richlea (9.2%) cultivars (i.e., green lentils) and CDC Maxim (9.4%) cultivar in the red market class (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 2.1 to 3.1% with a mean of 2.5% (Table 18). The mean ash content of lentils grown in 2017 was slightly lower than the 5-year mean of 2.6%. Ash content is a general indicator of minerals present. Furthermore, the difference in 0.1 percentage point is insignificant and thus the ash contents remain relatively constant over the last 5 years. The ash contents of the different market classes ranged between 2.4 and 2.7%, with Spanish brown having the highest ash content (Table 19). The Brewer (green) cultivar had the highest (2.9%) ash content followed by Merrit (green), CDC Redcliff (red) and Pardina (Spanish brown) cultivars (Table 20). The lowest (2.2%) ash was observed in the CDC Viceroy (green) cultivar.

Fat

Fat content of lentils ranged from 0.8 to 3.4% with a mean of 2.1% (Table 18). The fat content was measured for the first time as part of the survey and thus no historical data is available for comparisons. However, literature reports indicate that lentils have fat contents between 1 and 3%; therefore, the fat content of lentils grown in 2017 fall within the range reported by others. The difference of 0.1 to 0.2-percentage points was observed in the fat content between the market classes, which is insignificant (Table 19). CDC Viceroy (green) cultivar had the lowest (0.8%) fat content while Merrit (green) had the highest (2.7%) fat content among cultivars (Table 20).

Protein

Protein content of lentils averaged 23.5% in 2017 (Table 18). The protein content ranged from 20.6 to 27.6%. The mean protein content of lentils grown in 2017 was most similar to the lentils grown in 2013-2015 (i.e. 23-24%) and was nearly identical to the 5-year mean of 23.4%. The protein contents of the three market classes were different (Table 19). Red lentils had the highest mean protein content (24.3%) among lentil market classes while green and Spanish brown lentils had values of 23.2% and 23.6%, respectively. The Merrit (green) and CDC Meteor (green) cultivars had the highest and lowest protein, respectively, among known cultivars (Table 20).

Total starch

Total starch content of lentils ranged from 39.1 to 47.8%, with a mean of 44.0% (Table 18). The mean total starch content of lentils grown in 2017 was similar to the lentils from the 2014 and 2016 harvest years (i.e. 43-44%), but lower than the 5-year mean of 46.2%. The starch content of lentils from 2017 was less than those observed in 2012 and 2013 (52-54%).

The starch content of the red and Spanish brown market classes was 43.9% 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 2017 and lentils from the 2012 and 2013 crop years (Table 19). Red and green lentils had mean starch contents that were most similar to lentils from 2014 and 2016 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 Avondale (green) followed by the Morton and CDC Redcoat (both red lentils) (Table 20). The Merrit (green) cultivar had the lowest (40%) starch content among known cultivars tested (Table 20). In 2016, Merrit also had the lowest starch content.

Table 18. Proximate composition of lentils grown in the USA, 2012-2017.

Proximate Composition (%)	2017 Range	2017 Mean (SD)	2016 Mean	2015 Mean	2014 Mean	2013 Mean	2012 Mean	5-year Mean (SD)
Moisture	7.0-10.7	8.8 (1.0)	9	10	11	5	8	8.6 (2.3)
Ash	2.1-3.1	2.5 (0.2)	2.5	2.7	2.5	2.4	2.8	2.6 (0.2)
Fat	0.8-3.4	2.1 (0.5)	**	**	**	**	**	nd
Protein	20.6-27.6	23.5 (1.7)	22	23	24	23	25	23.4 (1.1)
Total Starch	39.1-47.8	44.0 (2.0)	43	38	44	54	52	46.2 (6.6)

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

Table 19. Proximate composition* of different market classes of lentils grown in the USA, 2012-2017.

Market Class	Proximate Composition (%)	Mean (SD) 2017	2016	2015	2014	2013	2012	5-Year Mean (SD)
Green	Moisture	9.0 (0.8)	9.2 (0.9)	9.8 (1)	10.9 (1.2)	5 (1)	9 (1)	9(2)
	Ash	2.4 (0.2)	2.5 (0.2)	2.9 (0.2)	2.4 (0.1)	2.3 (0.2)	2.7 (0.2)	2.6 (0.2)
	Fat	2.1 (0.5)	**	**	**	**	**	nd
	Protein	23.2 (1.7)	21.4 (1.5)	22.5 (1)	23.2 (1.5)	23 (3)	25 (2)	23 (1)
	Total Starch	44.0 (2.1)	43.3 (3.2)	38.5 (2)	44.6 (3.5)	55 (6)	52 (3)	47 (7)
Red	Moisture	8.6 (1.2)	9.3 (0.8)	10.4 (1)	10.0 (0.8)	5 (3)	8 (0.3)	8 (2)
	Ash	2.5 (0.2)	2.6 (0.2)	2.7 (0.4)	2.9 (0.6)	2.6 (0.4)	3.0 (0.2)	2.8 (0.2)
	Fat	2.0 (0.5)	**	**	**	**	**	nd
	Protein	24.3 (1.5)	23.3 (1.2)	22.8 (2)	24.2 (1.3)	25 (2)	25 (2)	24 (1)
	Total Starch	43.9 (2.0)	44.9 (1.8)	39.1 (2)	41.2 (0.6)	52 (5)	53 (4)	46 (6)
Spanish Brown	Moisture	8.2 (0.7)	7.8 (0.7)	8.9 (1)	9.7	**	**	nd
	Ash	2.7 (0.2)	2.5 (0.3)	2.9 (0.2)	2.2	**	**	nd
	Fat	2.2 (0.5)	**	**	**	**	**	nd
	Protein	23.6 (1.2)	20.7 (1.0)	22.8 (1)	22.2	**	**	nd
	Total Starch	43.9 (1.7)	41.1 (2.8)	36.8 (4)	42.5	**	**	nd

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

Table 20. Mean proximate composition of lentil cultivars grown in the USA in 2017.

		Concentration (%)				
Market Class	Cultivar	Moisture	Ash	Fat	Protein	Starch
Green	Avondale	9.3	2.5	2.1	22.3	46.9
	Brewer	8.4	2.9	1.9	24.3	44.3
	CDC Meteor**	9.3	2.4	2.4	21.1	44.6
	CDC Richlea	9.2	2.3	2.1	22.7	44.4
	CDC Viceroy**	8.4	2.2	0.8	25.5	42.6
	Eston	8.2	2.3	2.0	24.4	43.3
	Merrit	8.1	2.8	2.7	26.3	40.0
Red	CDC Maxim	9.4	2.5	1.9	24.8	42.6
	CDC Redcoat**	9.2	2.6	2.2	22.6	45.8
	CDC Redcliff	7.5	2.7	1.3	24.5	43.5
	Morton**	7.0	2.6	1.9	23.8	46.0
	Unknown	8.6	2.4	2.4	24.2	44.1
Spanish Brown	Pardina	8.2	2.7	2.2	23.6	43.9

*Composition is on an "as is" basis; **Only one sample of cultivar tested

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 6132 to 8345 mg/kg, with a mean value of 7022 mg/kg. Phosphorus content ranged from 2030 to 3473, with a mean of 2763. Magnesium content in lentils fell between 933 and 1177 mg/kg and averaged 1039 mg/kg. Calcium content of all lentils was 502 mg/kg and varied from 357 to 752 mg/kg. Other minerals had similar variability, but to a lesser extent.

The potassium content of lentil classes from 2017 tended to be higher

Table 21. Mineral concentrations of lentils grown in the USA, 2012-2017.

Market Class	Mineral	2017 mean (std dev.)	2016 mean (std dev.)	2015 mean (std dev.)	2014 mean (std dev.)	2013 mean (std dev.)	2012 mean (std dev.)	5-year Mean
Green	Calcium	493 (69)	534 (67)	449 (54)	761 (89)	496 (81)	293 (79)	507 (169)
	Copper	9 (1)	6 (1)	7 (1)	7 (1)	7 (2)	*	nd
	Iron	63 (10)	62 (14)	80 (38)	61 (9)	57 (18)	69 (39)	66 (9)
	Magnesium	1048 (48)	1026 (67)	1149 (75)	789 (27)	597 (185)	367 (109)	786 (316)
	Manganese	14 (3)	12 (3)	13 (2)	17 (4)	15 (4)	*	nd
	Phosphorus	2632 (351)	3890 (744)	2625 (359)	2574 (156)	2931 (829)	*	nd
	Potassium	7057 (450)	5401 (506)	6111 (791)	8493 (295)	6936 (1463)	6954 (709)	6784 (1156)
	Zinc	37 (5)	25 (4)	27 (4)	40 (4)	35 (10)	34 (8)	32 (6)
	Selenium (µg/kg)	236 (54)	179 (33)	279 (32)	369 (37)	727 (382)	726 (403)	456 (256)
Red	Calcium	530 (102)	573 (92)	590 (177)	647 (38)	460 (56)	418 (85)	538 (95)
	Copper	9 (1)	7 (1)	7 (1)	7 (1)	7 (3)	*	nd
	Iron	74 (12)	64 (12)	123 (90)	62 (5)	75 (28)	79 (18)	81 (25)
	Magnesium	1016 (41)	1035 (87)	1145 (90)	772 (23)	677 (175)	482 (83)	822 (269)
	Manganese	15 (3)	15 (3)	15 (2)	13 (1)	20 (5)	*	nd
	Phosphorus	2906 (232)	3569 (625)	2695 (162)	2960 (177)	3909 (1491)	*	nd
	Potassium	6808 (423)	5637 (939)	5962 (575)	8416 (730)	7761 (2607)	7243 (896)	7004 (1181)
	Zinc	38 (6)	27 (7)	29 (6)	41 (6)	45 (16)	40 (4)	36 (8)
	Selenium (µg/kg)	223 (51)	189 (28)	269 (32)	397 (30)	379 (143)	503 (174)	347 (121)
Spanish Brown	Calcium	496 (40)	479 (64)	457 (34)	*	*	*	nd
	Copper	8 (1)	6 (1)	8 (1)	*	*	*	nd
	Iron	68 (14)	62 (21)	109 (43)	*	*	*	nd
	Magnesium	1036 (38)	934 (38)	1168 (75)	*	*	*	nd
	Manganese	16 (2)	10 (2)	14 (2)	*	*	*	nd
	Phosphorus	3242 (151)	4722 (437)	3137 (289)	*	*	*	nd
	Potassium	7304 (474)	4997 (303)	6609 (791)	*	*	*	nd
	Zinc	43 (2)	28 (4)	33 (5)	*	*	*	nd
	Selenium (µg/kg)	169 (15)	166 (32)	239 (47)	*	*	*	nd

*data not reported previously; nd= not determined overall than the previous years (Table 21). The lentils from 2017 had mean potassium levels of 6808 mg/kg in red lentils to 7304 mg/kg in the Spanish brown class. Phosphorus content in Spanish brown lentils was approximately 3242 mg/kg while in red and green lentils the phosphorus contents were 2906 and 2632 mg/kg, respectively. The phosphorus contents of the 2017 green lentil class was higher than in lentils from 2014 and 2015, but lower than in samples from 2013 and 2016 (Table 21). The phosphorus content red and Spanish brown market classes were lower than previous harvest years except 2015. Calcium in green lentils from 2017 was comparable to the lentils from 2013 and 2015 harvest years, but lower than the 5-year mean value. Red lentils from 2017 had calcium contents higher than 2012-2013 harvest years, similar value as the 5-year mean, but lower calcium contents than lentils from 2014-2016 harvest years (Table 21). Calcium content of the Spanish brown lentils was higher in 2017 compared to lentils from other harvest years. Magnesium composition in lentils from 2017 tended to be higher than the 5-year values, but generally lower than the content found in the lentils from 2015, regardless of market class. The trace mineral (i.e., copper, manganese) content in lentils had values that were either similar or slightly higher than values from previous harvest years. The iron contents of lentils harvested in 2017 were lower than those values reported in 2015, comparable to lentils from previous years (2011-2014) and slightly lower than the 5-year mean iron content (Table 21). Mean zinc and selenium (other trace minerals) contents of lentils, regardless of market class, grown in 2017 were significantly lower than the mean zinc and selenium contents from 2011-2014, but comparable to lentils from 2015 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 mineral (i.e. calcium, magnesium, potassium, phosphorus) varied widely among cultivars. For example, Morton had a calcium content of 419 mg/kg while CDC Redcoat contained 655 mg/kg. In 2016, CDC Redcoat had a calcium content of 417 mg/kg, suggesting that growing location likely impacted calcium content. The CDC Viceroy cultivar had a magnesium content of 974 mg/kg while 1108 mg/kg was observed in the Brewer cultivar. The Brewer and Eston cultivars had the highest and lowest potassium contents, respectively (Table 22). The CDC Richlea cultivar had a mean phosphorus content of 2504 mg/kg while 3306 mg/kg was observed in the Merrit cultivar. Variability existed in the trace minerals, but to a lesser degree (Table 22). Iron content ranged from 59 in CDC Richlea to 88 mg/kg in CDC Redcoat while selenium ranged from 169 µg/kg in the Pardina cultivar to 314 µg/kg in the CDC Meteor cultivar. The CDC Meteor also had the highest selenium content in 2016.

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 2017 and comparisons to the 5-year mean values when applicable.

Test weight ranged from 56-67 lbs/bu with a mean of 62 lbs/bu. This mean value was the same as the 5-year mean of 62 lbs/bu (Table 23). The test weight for all lentil samples harvested in 2017 was comparable to lentils harvested in previous years. The mean test weight of lentils in the Spanish brown market class was 1 to 3 percentage points higher than test weights of lentils from

Table 22. Mean mineral concentrations of lentil cultivars grown in the USA in 2017.

		Concentration (mg/kg)*								(µg/kg)
Market Class	Cultivar	Ca	Cu	Fe	K	Mg	Mn	P	Zn	Se
Green	Avondale	597	7	60	7024	1041	16	2581	32	199
	Brewer	461	10	86	8167	1108	22	3246	43	175
	CDC Meteor**	558	10	60	7129	1049	13	2596	34	314
	CDC Richlea	486	8	59	6983	1040	13	2504	36	241
	CDC Viceroy**	435	8	83	6568	974	11	2710	29	265
	Eston	505	10	66	6407	1053	14	2689	39	291
	Merrit	497	10	71	7548	1105	19	3306	42	184
Red	CDC Maxim	637	9	69	6892	1045	14	2930	37	218
	CDC Redcoat**	655	10	88	7048	1071	14	3057	41	266
	CDC Redcliff	481	8	76	7196	1009	18	2967	44	172
	Morton**	419	8	83	6894	1030	14	3177	33	186
	Unknown	472	9	73	6569	987	15	2799	38	243
Spanish Brown	Pardina	496	8	68	7304	1036	16	3242	43	169

*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

the red and green market classes (Table 24). Maximum test weight of 67 lbs/bu was observed for the Morton cultivar. The closest test weight to that observed in Morton was 64 lbs/bu in CDC Viceroy (green) and Pardina (Spanish brown) cultivars (Table 25). The lowest mean test weight (58 lbs/bu) was found in the Brewer cultivar.

The range and mean **1000 seed weight** of lentils grown in 2017 were 25 to 67 g and 44 g, respectively (Table 23). The mean value was the same as the 5-year mean of 44 g. Lentils of the red market class had a mean 1000 seed weight of 36 g, which was the same as the lentils from 2015 and 2016, but lower than the values of lentils from each of the prior harvest years. In contrast, lentils of the green market class had a mean 1000 seed weight of 48 g, which is higher than the previous 5 years (Table 24). 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. CDC Viceroy had the lowest 1000 seed weight at 25 g, followed by Morton (29 g). Merrit had the highest 1000 seed weight at 61 g, which was identical to the value measured in 2016.

Water hydration capacity of lentils ranged from 66 to 140%, with a mean of 101% (Table 23). The 2017 mean water hydration capacity value was higher than values in lentils from previous years except 2015, which had higher water hydration capacity. The 5-year mean water hydration capacities of 97% was lower than the mean water hydration in lentils from 2017. The water hydration capacity (103%) was highest for green lentils followed by the Spanish brown (102%) and red (95%) market classes (Table 24). The water hydration capacities of the green and Spanish brown were substantially lower than lentils from their respec-

Table 23. Physical parameters of lentils grown in the USA, 2012-2017.

Physical Parameters	2017 Range	2017 Mean (SD)	2016 Mean	2015 Mean	2014 Mean	2013 Mean	2012 Mean	5-year Mean (SD)
Test Weight (lb/Bu)	56-67	62 (2)	62 (3)	63	61	62	61	62 (1)
1000 Seed Wt (g)	25-67	44 (9)	45 (9)	43	44	46	45	44 (1)
Water Hydration Capacity (%)	66-140	101 (13)	91 (11)	118	94	90	94	97 (12)
Unhydrated Seeds (%)	0-11	1 (2)	4 (7)	1	2	7	7	4 (3)
Swelling Capacity (%)	104-223	144 (18)	140 (28)	161	102	*	*	nd
Cooked Firmness (N/g)	9.9-32.8	14.9 (3.9)	13.4 (2.5)	11.9	*	*	*	nd

*data not reported, nd = not determined

Table 24. Physical parameters of different market classes of lentils grown in the USA, 2012-2017.

Market class	Physical Parameter	2017	2016	2015	2014	2013	2012	5-Year Mean
Green	Test Weight (lb/Bu)	61 (2)	62 (2)	62 (2)	63 (3)	63 (2)	61 (1)	62 (1)
	1000 Seed Wt (g)	48 (8)	49 (8)	47 (9)	32 (5)	45 (6)	39 (11)	42 (7)
	Water Hydration Capacity (%)	103 (10)	95 (9)	121 (18)	94 (4)	82 (22)	85 (51)	95 (15)
	Unhydrated Seeds (%)	1 (1)	2 (4)	1 (1)	3.0 (1)	11 (7)	2 (3)	4 (4)
	Swelling Capacity (%)	148 (18)	148 (26)	148 (32)	103 (9)	*	*	nd
	Cooked Firmness (N/g)	15.1 (4.4)	13.5 (2.8)	12.5 (2.0)	*	*	*	nd
Red	Test Weight (lb/Bu)	63 (3)	63 (4)	64 (1)	60 (3)	62 (1)	60 (2)	62 (2)
	1000 Seed Wt (g)	36 (6)	36 (3)	36 (2)	50 (9)	49 (7)	47 (11)	41 (6)
	Water Hydration Capacity (%)	95 (16)	87 (3)	98 (9)	95 (2)	89 (21)	98 (17)	89 (7)
	Unhydrated Seeds (%)	2 (2)	4 (3)	2 (1)	2.0 (1)	6 (8)	6 (7)	4 (4)
	Swelling Capacity (%)	132 (11)	125 (21)	155 (15)	105 (10)	*	*	nd
	Cooked Firmness (N/g)	14.9 (2.2)	13.2 (2.1)	12.0 (1.0)	*	*	*	nd
Spanish Brown	Test Weight (lb/Bu)	64(2)	66 (1)	64 (2)	66	*	*	nd
	1000 Seed Wt (g)	40 (10)	36 (2)	38 (8)	36	*	*	nd
	Water Hydration Capacity (%)	102 (15)	79 (16)	124 (6)	91	*	*	nd
	Unhydrated Seeds (%)	3 (4)	13 (13)	1 (1)	2	*	*	nd
	Swelling Capacity (%)	144 (18)	118 (26)	191 (23)	115	*	*	nd
	Cooked Firmness (N/g)	13.6 (3.3)	13.1 (0.8)	10.8 (1.3)	*	*	*	nd

*data not reported; nd = not determined

tive market classes in 2015 (Table 24). However, in the green market class the mean water hydration was higher than those observed in 2012-2014 and 2016. The red and Spanish brown market classes had mean water hydration capacities that were lower than lentils from 2015, but tended to be higher than values from other previous crop years. The water hydration capacity ranged from 72% in Morton (red) to 121% in Brewer (green). Most other cultivars ranged from 96 to 103% (Table 25).

Unhydrated seed percentage ranged from 0 to 11% with a mean of 1%, which was less than the 5-year mean of 4% (Table 23). The unhydrated seed percentage was lower in 2017 lentils compared to lentils from other harvest years except 2015. The amount of unhydrated seeds in all market classes varied from 1 to 3% (Table 24). The green and red lentils from 2017 had lower unhydrated seeds amounts compared to the unhydrated seeds from the previous five years except 2015. The unhydrated seed count in the Spanish brown lentils from 2017 were significantly lower than for lentils from 2016. A number of cultivars had the no unhydrated seeds while CDC Maxim had the highest at 4% (Table 25). The unhydrated seed numbers obtained in 2017, for specific cultivars, tended to be lower than these same cultivar harvested in 2016.

The **swelling capacity** of all lentils ranged from 104 to 223%, with a mean value of 144% (Table 23). The swelling capacity from 2017 samples was greater than that of lentils from the 2014 harvest and similar to the lentils from 2016, but lower than swelling capacities of lentils from the 2015 harvest year. The swelling capacity of lentils was similar between green and Spanish brown market classes (Table 24). Swelling capacities of 148% was observed in the green market class for lentils grown in 2017, which was identical to swelling capacities in the 2015 and 2016 lentils. Brewer had the greatest swelling capacity (199%) followed by CDC Meteor (Table 25). Morton had the lowest swelling capacity among the cultivars tested (Table 25).

The **cooked firmness** of all lentils ranged from 9.9 to 32.8 N/g with a mean value of 14.9 N/g (Table 23). The lentils from 2017 had slightly greater cooked firmness values than lentils from 2016. The cooked firmness of lentils was not significantly different between market classes (Table 24), although Spanish brown lentils were slightly less firm than lentils from the green market classes. However, the 2017 lentils from their respective market classes were firmer than lentils from 2015 and 2014. Among the cultivars, Brewer had the lowest cooked firmness while Merrit was the firmest (Table 24). This test generally supports the swelling capacity test, where lentils with higher swelling capacities generally have lower cooked firmness and vice versa. However, in 2017 this trend was observed for only the Brewer cultivar.

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 all market classes in 2017 indicated that the lentils had slightly greater L* values than in lentils from 2016, but lower L* values compared to lentils from other crop years (2012-2015). This data indicates that the lentils from the 2017 crop year were darker in color than those from previous years, except 2016. 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 2017, the "a" value of 5.32 was higher than values from other years. This indicates that the lentils from 2017 were slightly less green than the lentils from previous harvest years (Table 26).

Table 25. Mean physical parameters of USA lentil cultivars grown in 2017.

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	50	93	1	137	17.33
	Brewer	58	55	121	0	199	10.18
	CDC Meteor**	62	49	103	0	149	17.10
	CDC Richlea	61	49	101	1	147	14.69
	CDC Viceroy**	64	25	93	1	124	12.98
	Eston	63	30	96	2	132	10.91
	Merrit	59	61	114	2	148	22.76
Red	CDC Maxim	61	36	96	4	133	15.01
	CDC Redcoat**	62	44	92	3	133	16.91
	CDC Redcliff	63	44	101	3	131	18.71
	Morton**	67	29	72	3	104	11.49
	Unknown	64	34	96	1	136	13.94
Spanish Brown	Pardina	64	40	102	3	144	13.62

**Only one sample of cultivar tested

In the red lentil market class, the 2017 samples were less green based on the higher “a” values compared to previous years except 2016 (Table 26). The Spanish brown “a” value was slightly higher than lentils from previous year; therefore, indicating more redness in the sample. The “b” value for green lentils from 2017 indicated a yellower color compared to the previous years except lentils from the 2013 and 2016 crop years. The “b” value for red lentils from 2017 indicated a less yellow color compared to lentils from the previous crops years except 2012 and 2014.

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 the 2013 and 2016 for the green and red market classes. The green lentil lightness value increased after soaking also occurred in the 2015 green lentils. In the red lentil market class, a trend to increasing redness was observed in lentil from 2012-2016 after soaking, this same trend occurred in 2017. The Spanish brown redness value also increased upon soaking of the lentil. In contrast, the “a” value decreased in soaked lentils from 2017, supporting a greener color for the soaked lentils in the green market class. Lentils from all market classes became more yellow (i.e., increased b value) after soaking. The color changes in all lentil samples were similar for the red and Spanish brown market classes (Table 26). The color difference values were similar to the values observed in 2014 and 2016, but higher than those from the 2015 harvest year. The green market class had lower color differences compared to the red and Spanish brown market classes, indicating greater color stability among these lentils. This general observation was also true for the green lentils from 2014 and 2016.

Among the cultivars, Pardina had the lowest L* value followed by CDC Redcoat (Table 27). The highest L* was Avondale. This follows expectations that the brown lentils would be darker than the green lentils. The L* value of lentil increased after soaking with Avondale and CDC Meteor having the highest values (Table 27). These two cultivars also had the highest L* value in the 2016 lentil evaluation. 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. The “b” value increased substantially in all lentils during soaking. The green lentil cultivar CDC Meteor had the highest “b” value (i.e. yellowness) of the soaked lentils. This is a green coated lentil, but has a yellow cotyledon; thus, the soaking may have reduced the impact of the hull on color and resulted in increased yellowness. The greatest color difference was

Table 26. Color quality of lentils grown in the USA before and after soaking, 2012-2017.

	Mean (SD) of red lentils											
	Before soaking						After soaking					
Color scale*	2017	2016	2015	2014	2013	2012	2017	2016	2015	2014	2013	2012
L (lightness)	56.13 (2.29)	55.22 (1.19)	57.14 (5.76)	63.12 (0.93)	60 (2)	60 (1)	57.26 (2.11)	58.23 (2.01)	62.29 (1.18)	59.91 (2.28)	67 (7)	59 (2)
a (red-green)	5.32 (1.15)	4.69 (1.42)	2.49 (2.17)	2.25 (1.56)	1 (2)	1.1 (1)	4.71 (1.24)	4.06 (1.42)	0.59 (1.79)	0.59 (2.19)	-0.2 (2)	-0.4 (1)
b (blue-yellow)	22.11 (1.46)	23.16 (1.38)	19.55 (5.02)	15.36 (0.22)	23 (1)	15 (1)	31.98 (2.60)	32.30 (2.60)	28.30 (1.62)	25.79 (2.15)	35 (6)	23 (2)
Color Difference	10.42 (1.85)	9.82 (1.96)	6.18 (1.62)	11.10	**	**						

	Mean (SD) of green lentils											
	Before soaking						After soaking					
Color scale*	2017	2016	2015	2014	2013	2012	2017	2016	2015	2014	2013	2012
L (lightness)	46.19 (3.87)	45.95 (1.70)	56.84 (5.35)	56.06 (0.54)	54 (8)	55 (2)	48.95 (3.12)	49.54 (0.75)	52.51 (0.60)	51.82 (0.16)	57 (8)	52 (3)
a (red-green)	7.40 (1.28)	7.97 (0.63)	3.71 (1.63)	4.19 (0.69)	5.4 (1)	3.9 (1)	12.63 (2.99)	13.84 (1.08)	8.64 (0.22)	7.83 (0.32)	10 (2)	7.7 (1)
b (yellow-blue)	13.93 (2.82)	14.34 (1.34)	18.58 (4.60)	7.57 (1.20)	15 (4)	9 (2)	28.18 (2.89)	27.04 (1.85)	20.29 (1.45)	21.98 (0.58)	28 (7)	19 (1)
Color Difference	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*	2017	2016	2015	2014	2013	2012	2017	2016	2015	2014	2013	2012
L (lightness)	44.59 (3.55)	42.92 (1.12)	55.71 (5.26)	54.5	**	**	48.84 (3.04)	47.88 (1.69)	51.21 (2.82)	54.3	**	**
a (red-green)	6.11 (1.02)	5.21 (0.20)	3.43 (2.79)	2.2	**	**	7.66 (1.04)	6.59 (0.45)	4.66 (0.69)	0.99	**	**
b (yellow-blue)	13.18 (2.50)	12.07 (0.94)	17.95 (4.79)	6.65	**	**	28.52 (3.85)	26.59 (1.31)	19.54 (1.84)	23.91	**	**
Color Difference	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

observed in the CDC Maxim cultivar (Table 27). The increase in redness and yellowness during soaking likely contributed to the greatest color difference in this cultivar. The color of Avondale 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 2017 were higher than lentils from 2012-2016. Only lentils harvested in 2011 had greater pasting properties than lentils from 2017 (Table 28). Mean peak time was significantly less than the 5-year mean value, but was similar to peak times measured in lentils from 2014-2016 harvest years. Pasting temperature ranged from 75 to 82°C, with a mean value of 77.8 °C. 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 256, 241 and 264 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 greater than those from the 2012, 2014 and 2015 harvest years. Only the lentils from 2011 had viscosity values greater than those from the 2017 crop year.

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 (117 RVU), hot paste (114 RVU), and cold paste (205 RVU) viscosities among the green lentil cultivars. In contrast, CDC Richlea had the highest viscosity values (Table 30). In 2016, CDC Richlea also had the highest pasting viscosities. The CDC Redcoat cultivar had highest peak, hot paste and cold paste viscosities among cultivars tested. However, paste viscosities were highest in red lentils of unknown cultivars.

Table 27. Color quality of USA lentil cultivars before and after soaking, 2017.

		Mean Color Values*						
		Before Soaking			After Soaking			
Market Class	Cultivar	L	a	b	L	a	b	Color Difference
Green	Avondale	58.04	4.63	21.39	59.68	3.71	28.14	7.40
	Brewer	50.28	7.70	18.86	53.57	6.43	28.13	10.04
	CDC Meteor**	56.28	6.07	22.84	57.78	4.54	33.73	11.11
	CDC Richlea	56.85	5.03	22.79	57.58	4.54	32.83	10.60
	CDC Viceroy**	52.01	4.62	20.32	55.25	3.29	32.56	12.74
	Eston	56.65	3.76	21.54	56.92	3.01	33.09	11.64
	Merrit	53.44	7.68	19.60	56.02	7.35	28.21	9.33
Red	CDC Maxim	47.89	7.56	14.13	48.49	14.34	28.83	16.57
	CDC Redcoat**	47.13	7.38	11.46	49.47	14.24	24.88	15.29
	CDC Redcliff	49.31	8.12	15.91	51.56	15.26	28.44	14.69
	Morton**	51.28	9.81	19.89	53.58	14.75	33.67	14.94
	Unknown	43.01	6.65	12.57	47.52	10.00	27.29	16.10
Spanish Brown	Pardina	44.59	6.11	13.18	48.84	7.66	28.52	16.16

*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. Pasting characteristics of lentils grown in the USA, 2011-2017*.

	2017		2016	2015	2014	2012	2011	5-year
Starch Characteristic	Range	Mean (SD)	Mean	Mean	Mean	Mean	Mean	Mean (SD)
Peak Viscosity (RVU)	88-169	143 (17)	148 (20)	124	121	119	185	139 (28)
Hot Paste Viscosity (RVU)	86-156	136 (15)	133 (18)	119	115	112	145	125 (14)
Breakdown (RVU)	1-19	7 (4)	15 (6)	4	6	7	41	15 (15)
Cold Paste Viscosity (RVU)	164-292	253 (28)	239 (31)	205	196	208	323	234 (52)
Setback (RVU)	74-141	117 (16)	106 (16)	86	81	96	178	109 (40)
Peak Time (Minute)	4.87-7.00	5.65 (0.52)	5.16 (0.26)	6	6	9.9	8.1	7.00 (2)
Pasting Temperature (°C)	75.0-82.4	77.8 (1.5)	75.9 (1.0)	77	76	**	**	nd

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

Table 29. Pasting characteristic of different market classes of lentils grown in the USA, , 2011-2017*.

Market class	Physical Parameter	Mean (SD)						4-Year Mean (SD)
		2017	2016	2015	2014	2012	2011	
Green	Peak Viscosity (RVU)	146 (16)	149 (22)	127 (17)	131 (12)	121 (14)	191 (19)	144 (28)
	Hot Paste Viscosity (RVU)	138 (13)	132 (20)	121 (14)	122 (9)	114 (11)	147 (13)	127 (13)
	Breakdown (RVU)	8 (5)	17 (6)	6 (5)	9 (5)	7 (7)	44 (7)	17 (16)
	Cold Paste Viscosity (RVU)	256 (26)	237 (35)	208 (25)	205 (25)	212 (3)	326 (45)	238 (51)
	Setback (RVU)	118 (16)	105 (18)	87 (14)	83 (17)	98 (15)	44 (7)	83 (24)
	Peak Time (Minute)	5.58(0.47)	5.10 (0.20)	6 (1)	5 (0)	10 (1)	8 (0)	6.82 (2.15)
	Pasting Temperature (°C)	77.7 (1.6)	76.0 (1.0)	77 (4)	76 (1)	**	**	nd
Red	Peak Viscosity (RVU)	134 (19)	141 (13)	112 (23)	106 (9)	99 (13)	174 (27)	126 (31)
	Hot Paste Viscosity (RVU)	129 (17)	132 (14)	108 (20)	104 (9)	96 (13)	138 (16)	116 (18)
	Breakdown (RVU)	5 (4)	9 (3)	4 (3)	2 (1)	4 (5)	36 914)	11 (14)
	Cold Paste Viscosity (RVU)	241 (32)	238 (18)	190 (33)	181 (14)	180 (30)	310 (49)	220 (56)
	Setback (RVU)	112 (19)	106 (12)	82 (15)	77 (6)	84 (20)	171 (34)	104 (39)
	Peak Time (Minute)	5.85(0.65)	5.47 (0.24)	6 (1)	6 (1)	11 (2)	8 (0)	7.29 (2.29)
	Pasting Temperature (°C)	78.1 (1.4)	75.9 (1.2)	76 (1)	77 (1)	**	**	nd
Spanish Brown	Peak Viscosity (RVU)	150 (12)	148 (14)	123 (10)	131 (12)	**	**	nd
	Hot Paste Viscosity (RVU)	144 (10)	135 (17)	121 (10)	122 (9)	**	**	nd
	Breakdown (RVU)	6 (3)	14 (4)	2 (1)	9 (5)	**	**	nd
	Cold Paste Viscosity (RVU)	264 (19)	247 (26)	210 (20)	205 (25)	**	**	nd
	Setback (RVU)	120 (11)	113 (12)	89 (11)	83 (17)	**	**	nd
	Peak Time (Minute)	5.59(0.27)	5.13 (0.26)	6 (1)	5 (0)	**	**	nd
	Pasting Temperature (°C)	78.0 (0.8)	75.7 (0.8)	79 (1)	76 (1)	**	**	nd

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

Table 30. Mean pasting characteristics of lentil cultivars grown in the USA in 2017.

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	128	123	5	228	105	5.50	77.1
	Brewer	142	138	4	247	109	5.57	78.7
	CDC Meteor**	151	142	10	263	121	5.27	76.6
	CDC Richlea	153	143	10	268	125	5.47	77.4
	CDC Viceroy**	135	133	2	228	95	6.00	78.4
	Eston	124	120	3	226	106	5.77	77.6
	Merrit	117	114	3	205	91	6.49	80.2
Red	CDC Maxim	122	118	4	216	98	6.27	78.7
	CDC Redcoat**	136	129	6	247	118	5.20	77.6
	CDC Redcliff	126	123	3	246	124	5.87	77.5
	Morton**	122	121	1	244	123	7.00	76.8
	Unknown	147	139	8	254	115	5.49	78.2
Spanish Brown	Pardina	150	144	6	264	120	5.59	78.0

**Only one sample of cultivar tested

Chickpea Quality

Sample distribution

A total of 37 chickpea samples were collected from Idaho, Montana, North Dakota and Washington between July and October 2017. Growing location, number of samples, market class, and genotype details of these dry pea samples are provided in Table 31. CDC Orion (9), CD Frontier (8) and Sierra (8) accounted for the majority of the chickpea evaluated.

Table 31. Description of chickpea samples used in the 2017 pulse quality survey.

State	No of samples	Market class	Cultivars	
Idaho	10	Kabuli	Billy Beans CDC Alma CDC Frontier CDC Leader	CDC Orion Sawyer Sierra
Montana	5	Kabuli	CDC Orion Sierra	
North Dakota	11	Kabuli	CDC Frontier CDC Orion	
South Dakota	1	Kabuli	CDC Frontier	
Washington/ Idaho	10	Kabuli	Bronic HB-14	Sierra Troy

Proximate composition of chickpea (Tables 32-33)

The **moisture content** of chickpeas ranged from 7.0 to 11.1% in 2017 (Table 32). The mean moisture content of the samples was 8.5%, which is slightly higher than the 5-year mean of 8%. Chickpeas grown in 2017 had a mean moisture content that was the same as chickpeas grown in 2012, 2015 and 2016, but lower than the 2014 mean moisture content of 11%. CDC Frontier had the highest moisture content at 9.2% while the Bronic and Billy Bean cultivars had the lowest moisture (7.7%). The moisture contents of all samples were below the 13% recommended for general storability. **Ash content** of chickpeas ranged from 1.8 to 3.2% with a mean of 2.8% (Table 32). The mean ash content of chickpeas grown in 2017 was comparable to other previous harvest years. CDC Orion and Sawyer had the lowest ash contents at 2.6% while Bronic, CDC Leader, HB-14 and Troy had the highest (3.0%) (Table 33).

Chickpeas mean **fat content** was 6.0% and ranged from 5.2 to 6.9% (Table 32). Literature reports indicate that chickpea has a fat content between 2 and 7%; therefore, the fat content of chickpeas grown in 2017 fall within the range reported by others. CDC Orion and CDC Alma had the highest (6.3%) fat contents while Bronic had the lowest (5.5%) fat content (Table 33). **Protein content** of chickpeas ranged from 16.2 to 23.6%, with a mean of 19.5% (Table 32). The mean protein content of chickpeas grown in 2017 was slightly lower than the 5-year mean of 20%, but was similar to the 2015 and 2016 crop. CDC Leader had a protein content of 17.1% while HB-14 had a protein content of 22.8% (Table 33). Growing conditions may have impacted protein content as the variability in protein was slightly higher than in 2016.

Total starch content of chickpeas ranged from 36.2 to 44.4%, with a mean of 39.6% (Table 32). The mean total starch content of chickpeas grown in 2017 was similar (i.e. 40%) to the mean starch content observed in 2012 and 2016 harvest years, but lower than the 5-year mean of 45%, primarily due to the higher starch composition observed in 2012 and 2013 (50-53%). The HB-14 cultivar had the lowest (36.3%) starch content while the highest (42.3%) was observed in the Sawyer cultivar.

Table 32. Proximate composition of Kabuli chickpeas grown in the USA, 2012-2017.

Proximate Composition**	Year							5-year
	2017		2016	2015	2014*	2013	2012	
	Range	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Moisture (%)	7.0-11.1	8.5 (0.9)	9 (1)	9 (1)	11 (1)	3 (2)	8 (1)	8 (3)
Ash (%)	1.8-3.2	2.8 (0.3)	2.7 (0.1)	2.7 (0.1)	2.5 (0.2)	2.8 (0.2)	2.9 (0.2)	2.7 (0.1)
Fat (%)	5.2-6.9	6.0 (0.4)	***	***	***	***	***	nd
Protein (%)	16.2-23.6	19.5 (2.0)	18 (1)	19 (1)	20 (2)	21 (2)	21 (2)	20 (1)
Starch (%)	36.2-44.4	39.6 (2.0)	40 (5)	41 (5)	42 (1)	53 (6)	50 (5)	45 (6)

*2014 data is for Frontier cultivar only; **composition is on an "as is" basis; ***data not reported previously; 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 content of chickpea was 7863 mg/kg in 2017, this values is less than the 5-year mean. However, the mean potassium content of chickpeas from 2017 was greater than the mean potassium contents in chickpea from 2012, 2015 and 2016. Phosphorus content in chickpea from 2017 was well below the phosphorus content of chickpeas from 2013, but similar to the phosphorus contents of chickpeas from 2014 and 2015. Both calcium and magnesium contents were higher in chickpea grown in 2017 compared to all previous years and were greater than the 5-year mean calcium and magnesium values (Table 34). The trace minerals (copper, iron, manganese and zinc) of chickpeas harvested in 2017 tended to be similar to or higher than values of chickpea from previous harvest years. Both iron and zinc were higher than the 5-year mean values (Table 34). Mean selenium (another trace mineral) content of chickpeas grown in 2017 was significantly lower than the mean selenium contents of chickpeas from the prior five years. However, the selenium content for chickpeas from 2017 equaled values from 2015 and were higher than the values obtained from 2016. 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 comparable among cultivars tested (Table 35). The Bronic cultivar contained the highest (1019 mg/kg) content of calcium while the Sierra cultivar contained the lowest (754 mg/kg). Interestingly, Bronic was observed to contain the lowest level calcium in 2016; thus, supporting the diversity of the chickpeas evaluated and the influence of growing location on mineral content. The CDC Frontier cultivar contained the lowest (7363 mg/kg) amount of potassium while the Troy cultivar had the highest (8554 mg/kg) potassium content. Phosphorus contents were lowest (2476 mg/kg) and highest (2958 mg/kg) in CDC Orion and Bronic, respectively (Table 35). Sawyer and HB-14 had the lowest (1225 mg/kg) and highest (1325 mg/kg) contents of magnesium, respectively. The selenium content ranged from 155 µg/kg in the CDC Alma cultivar to 278 µg/kg in the CDC Orion 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, 2017.

	Concentration (%)				
Cultivar	**Moisture**	**Ash**	**Fat**	**Protein**	**Starch**
Billy Bean*	7.7	2.9	5.6	21.3	37.0
Bronic*	7.7	3.0	5.5	22.5	38.3
CDC Alma*	7.8	2.9	6.3	18.4	42.0
CDC Frontier	9.2	2.6	5.7	19.3	40.1
CDC Leader*	8.8	3.0	6.1	17.1	38.3
CDC Orion	8.8	2.6	6.3	19.3	39.9
HB-14*	8.2	3.0	5.5	22.8	36.3
Sawyer*	8.3	2.6	6.1	19.5	42.3
Sierra	8.1	2.8	6.1	19.0	40.2
Troy	8.3	3.0	6.2	20.4	38.2
Unknown	8.4	2.8	6.4	19.4	38.6

* 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

Table 34. Mineral concentrations of chickpeas grown in the USA, 2012-2017.

	Year						
Micronutrient (mg/kg)	**2017 Mean (SD)**	**2016 Mean (SD)**	**2015 Mean (SD)**	**2014* Mean (SD)**	**2013 Mean (SD)**	**2012 Mean (SD)**	**5-year Mean**
Calcium	862 (136)	667 (154)	552 (114)	695 (75)	499 (238)	503 (158)	583 (92)
Copper	7 (1)	6 (1)	7 (1)	6 (1)	8 (2)	**	nd
Iron	51 (7)	41 (4)	48 (3)	46 (5)	51 (11)	43 (7)	46 (4)
Magnesium	1265 (36)	1226 (114)	1188 (48)	900 (8)	1148 (88)	693 (97)	1031 (228)
Manganese	41 (9)	35 (6)	29 (4)	33 (5)	44 (8)	**	nd
Phosphorus	2669 (227)	2882 (304)	2672 (189)	2642 (173)	3992 (1050)	**	nd
Potassium	7863 (573)	5928 (642)	7558 (362)	10,077 (372)	9670 (1340)	7627 (1382)	8172 (1702)
Zinc	30 (5)	21 (2)	28 (7)	35 (4)	38 (9)	30 (7)	29 (7)
Selenium (µg/kg)	221 (60)	173 (40)	227 (43)	376 (30)	520 (264)	599 (504)	379 (183)

*2014 data is for Frontier cultivar only; **data not reported; nd= not determined the range and mean value for 2017 and comparisons to the 5-year mean value.

Test weight ranged from 57-64 lbs/bu with a mean of 61 lbs/bu. This mean value is the same as the 5-year mean of 61 lbs/bu (Table 36). The test weights of individual cultivars ranged from 58 lbs/bu in Troy to 63 lbs/bu in the CDC Frontier and Sawyer cultivars. The range and mean **1000 seed weight** of chickpeas grown in 2017 were 279-607 g and 421 g, respectively (Table 36). The mean value was slightly higher than the 5-year mean of 407 g. The Troy cultivar had a highest 1000 seed weight at 561 g while the Billy Bean cultivar had the lowest value at 295 g (Table 37). These cultivars also had the highest and lowest 1000 seed weights in 2016.

Water hydration capacity of chickpeas ranged from approximately 85 to 148%, with a mean of 104% (Table 36). The water hydration capacity of chickpeas from 2017 was essentially the same as the 5-year mean of 106%. The CDC Alma cultivar had the highest water hydration capacity (148%) while CDC Frontier had the lowest (97%) (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). A number of cultivars had 0% unhydrated seed values and only the Bronic cultivar had a mean unhydrated seed value of 1% (Table 37). The **swelling capacity** of chickpeas ranged from 27 to 166%, with a mean value of 129% (Table 36). These values were higher than those reported in 2014, but lower than swelling capacities of chickpeas from 2015 and 2016. The Bronic cultivar had the greatest swelling capacity at 143% while the CDC Alma cultivar had the lowest (101%). In 2016, these two cultivars also had the highest and lowest swelling capacities. The swelling capacity of CDC Frontier cultivar has been evaluated since 2014. The swelling capacity of 105% (2014), 116% (2016), 136% (2017) and 138% (2015) were observed over the 4-year period. The **cooked firmness** was new for 2015 and thus comparisons are based on three years. The cooked firmness of all chickpea ranged from 16.5 to 30.0 N/g, with a mean value of 5.9 N/g (Table 36). The firmness of chickpea from the 2017 crop was slightly firmer than the chickpeas from 2015 and 2016, which had mean firmness values of 19.7 and 22.0 N/g, respectively. Although different, it is unlikely that consumers could detect this small difference. Among the cultivars, Bronic had the lowest cooked firmness while CDC Orion and Sawyer cultivars were 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 2017 was lower than the chickpea from previous years except chickpeas from 2016 (Table 38). In 2017, the "a"

Table 35. Mean mineral concentrations of chickpea cultivars grown in the USA, 2017.

	Year								µg/kg
Cultivar	**Ca**	**Cu**	**Fe**	**K**	**Mg**	**Mn**	**P**	**Zn**	**Se**
Billy Bean*	959	6	67	7964	1297	48	2893	31	164
Bronic*	1019	7	62	8049	1277	48	2958	37	168
CDC Alma*	785	6	54	8479	1237	63	2747	31	155
CDC Frontier	799	6	45	7363	1263	39	2501	25	253
CDC Leader*	902	9	52	8371	1264	37	2957	35	186
CDC Orion	953	7	47	7436	1247	34	2476	26	278
HB-14*	787	6	49	7999	1325	52	2927	31	177
Sawyer*	912	7	58	7740	1225	43	2570	28	230
Sierra	754	7	55	8210	1272	46	2732	32	182
Troy	924	7	55	8554	1295	44	2951	33	163
Unknown	885	8	49	8133	1260	37	2803	33	219

*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, 2012-2017.

	Year							
	2017		2016	2015	2014*	2013	2012	5-year
Physical Parameter	**Range**	**Mean (SD)**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean (SD)**
Test Weight (lb/Bu)	57-64	61 (2)	61 (2)	62	61	60	61	61 (1)
1000 Seed Wt	279-607	421 (72)	410 (106)	443	376	404	403	407 (24)
Water Hydration Capacity (%)	85-148	104 (13)	105 (15)	105	99	108	113	106 (5)
Unhydrated Seeds (%)	0-1	0 (1)	1 (1)	1	4	0	0	1 (2)
Swelling Capacity (%)	27-166	129 (27)	141 (12)	136	105	**	**	nd
Cooked Firmness (N/g)	16.5-41.5	25.9 (4.9)	22.0 (3.0)	19.7	**	**	**	nd

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

value of 8.55 was lower than values from 2013 and 2016, but higher than 2012, 2014 and 2015. This indicates that the chickpeas from 2017 were slightly less red than the 2013 and 2016 samples, but slightly redder then the chickpea from 2012, 2014 and 2015. The "b" value for chickpeas from 2017 indicated a less yellow color compared to the 2013 and 2015 crops, but yellower than the chickpea from 2012 and 2014 harvest years. The yellowness of the chickpeas from 2016 and 2017 were the same.

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 not change significantly after soaking. In contrast, chickpeas from all years became more yellow (i.e., increased "b" value) after soaking. The color difference between the pre- and post-soaked chickpeas was less in 2017 compared to 2014, but more than the change in 2015 (Table 38). This suggests better color stability of the chickpeas from 2015. Among cultivars, Troy had the highest L* value (60.09) while Billy Bean had the lowest (i.e. 50.41). In contrast, the Troy cultivar had the lowest yellowness value while the Billy Bean cultivar had the highest yellowness (Table 39). Visual observations support the color value differences as the Troy cultivar appear whiter in color than other cultivars. The Troy cultivar was the only cultivar that had a reduction in lightness during soaking, as evidenced by the reduction in the L* value of the soaked sample. This observation was also noted in the 2016 chickpea survey. The greatest color difference was observed in the CDC Alma cultivar (Table 39). The change in color observed in the CDC Alma cultivar was likely due to the significant increase in lightness and yellowness during the soaking.

Pasting properties (Tables 40-41)

Peak, hot and cold paste viscosities of chickpeas grown in 2017 were lower than the 5-year mean values (Table 40). The viscosity data indicated that the pasting properties of the 2017 chickpea crop were most similar to the chickpeas from 2015. The peak time was slightly lower than the 5-year mean value indicating a more rapid viscosity increase for the chickpeas harvested in 2017 compared to the 5-year mean value. The pasting temperature was slightly higher for the chickpeas from 2017 compared to chickpeas from 2014 and 2016.

Peak, hot and cold paste viscosities of the CDC Alma chickpea cultivar were greatest among cultivars tested (Table 41). In contrast, the cultivar Troy had the lowest peak viscosity while HB-14 had the lowest hot past and cold viscosities. CDC Orion had a hot paste viscosity identical HB-14; however, the cold paste viscosities were not the same. Other pasting properties were similar among cultivars tested.

Table 37. Mean physical properties of chickpea cultivars grown in the USA, 2017.

Cultivar	Test Weight (lb/Bu)	1000 Seed Wt	Water Hydration Capacity (%)	Unhydrated Seeds (%)	Swelling Capacity (%)	Cooked Firmness (N/g)
Billy Bean*	62	295	110	0	141	21.8
Bronic*	62	355	114	1	143	18.7
CDC Alma*	62	361	148	0	101	28.5
CDC Frontier	63	399	97	0	136	27.7
CDC Leader*	60	372	105	0	131	22.8
CDC Orion	62	408	98	0	132	26.9
HB-14*	61	478	106	0	131	21.1
Sawyer*	63	470	101	0	130	26.9
Sierra	60	463	102	0	116	24.8
Troy	58	561	115	0	142	23.6
Unknown	62	350	114	0	119	28.0

* Only one sample of cultivar tested

Table 38. Color quality of chickpeas grown in the USA before and after soaking, 2012-2017.

	Mean (SD) Color Values											
	Before Soaking						After Soaking					
Color scale*	**2017**	**2016**	**2015**	**2014**	**2013**	**2012**	**2017**	**2016**	**2015**	**2014**	**2013**	**2012**
L (lightness)	55.02 (2.38)	53.01 (3.01)	66.86 (4.22)	63.32 (2.61)	81 (12)	61 (2)	57.27 (1.74)	55.57 (1.04)	70.33 (4.07)	60.49 (8.02)	89 (11)	62 (1)
a (red-green)	8.55 (1.43)	9.09 (1.72)	7.83 (1.61)	5.55 (0.76)	11 (2)	6 (1)	10.85 (0.98)	11.44 (1.04)	6.97 (1.28)	7.01 (0.44)	13 (3)	7 (1)
b (yellow-blue)	21.28 (1.99)	21.14 (2.07)	22.19 (2.55)	14.19 (0.45)	28 (4)	15 (1)	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, 2017.

Cultivar	Mean Color Values**						
	Before Soaking			After Soaking			Color Difference
	L	a	b	L	a	b	
Billy Bean*	50.41	10.52	23.08	55.99	12.95	39.04	17.09
Bronic*	50.55	9.73	21.58	55.18	12.04	35.98	15.34
CDC Alma*	51.39	9.68	21.23	59.21	11.87	36.56	17.42
CDC Frontier	55.47	9.41	22.64	56.50	11.16	35.18	12.98
CDC Leader*	55.37	7.40	19.20	56.23	9.89	32.03	13.26
CDC Orion	54.43	9.50	22.83	57.48	11.27	35.51	13.09
HB-14*	52.32	8.37	20.70	54.93	11.43	33.25	13.21
Sawyer*	52.80	8.81	21.53	56.21	10.41	32.57	11.71
Sierra	55.29	7.54	19.88	57.84	10.19	32.86	13.67
Troy	60.09	5.26	16.87	58.32	9.08	30.14	14.20
Unknown	55.53	8.61	21.65	57.72	11.15	35.66	14.50

* 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, 2011-2017.

Starch Characteristic	Year*							5-year Mean (SD)
	2017		2016	2015	2014	2012	2011	
	Range	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	
Peak Viscosity (RVU)	90-172	133 (15)	139 (23)	126 (15)	143 (7)	178 (15)	119 (10)	141 (23)
Hot Paste Viscosity (RVU)	89-151	128 (13)	134 (22)	124 (14)	138 (7)	156 (11)	110 (8)	132 (17)
Breakdown (RVU)	1-29	5 (6)	6 (4)	3 (2)	5 (1)	23 (11)	9 (6)	9 (8)
Cold Paste Viscosity (RVU)	132-267	196 (29)	214 (70)	185 (24)	210 (2)	292 (46)	161 (16)	212 (49)
Setback (RVU)	35-116	68 (18)	80 (43)	62 (13)	17 (2)	136 (40)	50 (12)	69 (44)
Peak Time (Minute)	4.67-7.00	6.34 (0.70)	6.04 (0.61)	6 (0)	6 (0)	9.9 (1)	10.3 (1)	8 (2)
Pasting Temperature (°C)	71.8-79.9	75.2 (1.5)	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, 2017.

Cultivar	Peak Viscosity (RVU)	Hot Paste Viscosity (RVU)	Breakdown (RVU)	Cold Paste Viscosity (RVU)	Setback (RVU)	Peak Time (Min)	Pasting Temperature (°C)
Billy Bean*	132	128	4	181	52	5.93	75.0
Bronic*	135	130	4	186	56	6.27	76.7
CDC Alma*	161	149	12	221	72	5.73	75.1
CDC Frontier	141	132	9	203	71	6.29	74.8
CDC Leader*	141	136	6	185	49	6.20	75.9
CDC Orion	127	123	4	191	68	6.14	74.4
HB-14*	128	123	5	175	52	6.13	75.8
Sawyer*	136	131	6	199	69	5.93	74.3
Sierra	131	129	2	202	73	6.77	75.9
Troy	126	125	2	197	72	6.80	75.6
Unknown	132	127	4	192	65	6.12	75.8

* 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. 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 210% for all peas (Table 42). There was essentially no difference in water hydration capacity between the green (211%) and yellow (210%) market classes. In comparison, water hydration capacities of peas during the soak test were 107 and 102% for green and yellow peas, respectively. Water hydration capacities ranged from 146 to 276% for all peas. In green peas, Arcadia and CDC Striker had the lowest water hydration capacity at 169% while Aragorn had the highest at 236%. In yellow cultivars, CDC Leroy had the lowest (187%) water hydration capacity while the Gambit cultivar had the highest (268%) 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. For example, Majoret and CDC Striker had the lowest (92%) and highest (135%) water hydration capacities, respectively, in the soak test, but Majoret had a higher water hydration capacity in the canning evaluation than CDC Striker (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 138 to 250%, with a mean value of 204% (Table 42). Arcadia had the lowest swelling capacity at 163% while Aragorn had the highest at 218%. These observations mirrored the outcome of the water hydration capacity test. In yellow cultivars, CDC Leroy and Mystique had the lowest (179%) swelling capacity while the Gambit cultivar had the highest (250%) value. Again, these results mirrored the water hydration capacity test for canned peas. The similarities in the performance of the cultivars in the soak test did not match the results between water hydration and swelling capacity of the canning test.

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 5.3 N/g (Table 42). In comparison, the mean cooked firmness for all peas was 24 N/g (Table 9). As expected, the canned peas were less firm than the cooked peas. The Aragorn cultivar was the least firm while Arcadia was the firmest (Table 43). These results coincide with the outcome of the water hydration capacity and swelling capacity outcomes. For example, Aragorn had the greatest swelling and water hydration among green cultivars and the lowest firmness. This would be expected since more water retained by the peas would result in a softer texture. In contrast, a similar trend was not observed in the yellow pea cultivars. DS Admiral was the least firm canned yellow pea while Nette had the highest firmness.

The color of the dry peas changed after the canning process. The color difference fell between 3.66 and 21.10, with a mean value of 13.25 for all peas, and 16.66 and 10.89 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 L* or lightness decreased during canning for both green and yellow market classes. In the soak test, only the green cultivars darkened upon soaking. The greatest color difference was observed in the Ariel cultivar after canning (Table 43). This same cultivar also had the greatest color difference in the soak test (Table 13). The Journey cultivar had the lowest color difference among the green cultivar after

Table 42. Mean physical and color parameters of canned dry peas grown in 2017.

Sample**	Hydration Capacity (%)	Swelling Capacity (%)	Canned Firmness (N/g)	Before Canning *			Post Canning*			Color Difference
				L	a	b	L	a	b	
All	210	204	5.3	56.26	3.54	18.24	51.32	4.72	29.45	13.25
Green	211	200	4.9	52.69	-1.24	15.11	46.27	2.45	29.23	16.66
Yellow	210	207	5.5	58.73	6.84	20.40	54.80	6.29	29.60	10.89

*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

canning. In the yellow cultivars, Hyline and Mystique 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).

Chickpeas

The mean **water hydration capacity** of canned chickpea was 123% (Table 44). Unlike pea, water hydration capacity (129%) of chickpea during the soak test was similar to canned chickpea water hydration capacity (123%). Water hydration capacities ranged from 107 to 142% for all chickpea. CDC Frontier and CDC Orion had the lowest water hydration capacity at 119% while Billy Bean had the highest at 142%. In the soak test, CDC Frontier and CDC Orion had the lowest water hydration capacities, which matched the outcome of the canning results. However, Billy Beans did not have the highest water hydration 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 134 to 198%, with a mean value of 168% (Table 44). CDC Frontier had the lowest mean swelling capacity at 156% while Bronic had the highest at 188%.

The **canned firmness** values of chickpeas were significantly lower than the cooked firmness values of soaked chickpeas. The mean canned firmness value of all peas was 10.4 N/g (Table 44). In comparison, the mean cooked firmness for all chickpeas was 25.9 N/g (Table 9). As expected, the canned chickpeas were less firm than the cooked chickpeas. The CDC Leader cultivar was the least firm while CDC Frontier was the firmest (Table 44). These results coincide with the outcome of the

Table 43. Mean physical and color parameters of canned pea cultivars grown in 2017.

		Mean Color Values*							Canned	Hydration	Swelling
		Before Canning			Post Canning			Color	Firmness	Capacity	Capacity
Market Class	Cultivar	L	a	b	L	a	b	Difference	(N/g)	(%)	(%)
Green	Aragorn	54.10	-1.62	14.30	47.72	2.60	29.59	17.54	4.0	236	218
	Arcadia**	55.49	-1.50	15.25	41.83	2.27	25.73	17.64	6.9	169	163
	Ariel	53.01	-1.60	12.31	47.59	2.21	29.69	18.84	4.8	234	198
	Banner	47.33	-1.94	15.53	44.07	2.92	30.81	17.13	5.7	200	212
	CDC Striker	57.03	0.28	15.51	46.58	3.55	28.27	16.99	5.4	169	164
	Columbian**	50.98	-1.13	16.27	48.15	2.11	28.71	13.17	6.2	209	200
	Ginny	54.02	-1.76	14.89	46.36	2.51	29.25	17.17	4.5	213	197
	Greenwood	50.80	-1.96	14.79	47.73	2.18	29.79	16.35	4.7	225	206
	Hampton**	54.93	-1.52	15.76	48.13	2.03	28.47	14.96	6.0	194	204
	Journey**	49.00	-2.68	16.72	44.28	1.47	24.67	10.54	4.6	226	201
	Majoret**	54.02	-0.68	13.79	46.58	2.19	25.99	14.62	5.4	221	190
	Shamrock	50.70	-0.50	18.72	44.06	2.98	31.12	14.61	5.1	177	167
	Unknown	53.49	-0.61	14.77	46.44	2.24	29.15	17.16	4.7	213	203
Yellow	AAC Craver	59.50	7.92	21.05	55.06	6.32	27.18	12.85	5.3	213	209
	AC Earlystar	61.20	6.55	19.49	56.88	5.66	30.95	12.37	3.9	243	225
	Agassiz	59.92	6.52	18.64	55.90	5.71	28.31	10.91	3.8	218	203
	CDC Amarillo	59.10	7.62	20.42	56.41	5.53	28.93	9.55	4.2	222	218
	CDC Leroy	58.06	6.12	20.78	55.68	6.08	30.54	10.27	6.4	187	179
	CDC Meadow**	57.32	7.11	22.52	51.48	6.57	33.58	12.53	4.4	215	218
	DS Admiral**	57.81	7.77	18.68	56.87	5.67	31.60	13.15	3.7	233	228
	Gambit**	58.08	6.34	18.70	55.82	6.11	27.72	9.35	4.7	268	250
	Hyline	58.82	6.67	19.78	55.24	6.85	32.56	13.44	3.8	224	218
	Mystique	58.74	8.21	21.89	57.71	6.29	26.74	5.56	5.1	214	179
	Nette	57.81	7.48	22.18	53.73	6.88	30.14	9.69	7.5	191	187
	Salamanca**	57.93	6.63	20.04	54.20	5.41	27.64	8.57	4.5	202	215
	Spider	57.00	6.21	19.00	56.38	4.76	28.13	9.29	4.9	212	183
	Trapeze**	59.82	6.43	21.32	52.34	6.05	31.53	12.70	5.4	188	237
	Universal**	59.49	6.46	19.63	57.17	8.06	32.83	13.56	4.5	224	233
	Unknown	59.10	6.72	20.62	54.03	6.74	29.73	10.88	6.3	202	211

Table 44. Mean physical and color parameters of canned chickpea cultivars grown in 2017.

Cultivar	Mean Color Values* Before Canning L	a	b	Post Canning L	a	b	Color Difference	Canned Firmness (N/g)	Hydration Capacity (%)	Swelling Capacity (%)
All Cultivars	55.02	8.55	21.28	45.85	7.91	24.27	10.45	10.4	123	168
Billy Bean**	50.41	10.52	23.08	46.53	7.21	24.58	5.42	9.8	142	184
Bronic**	50.55	9.73	21.58	48.13	9.97	27.89	6.79	8.5	138	188
CDC Alma**	51.39	9.68	21.23	44.34	9.82	26.03	8.54	9.9	127	181
CDC Frontier	55.25	9.41	22.60	45.30	8.18	23.30	11.06	11.5	119	156
CDC Leader**	55.37	7.40	19.20	48.16	5.31	19.31	7.53	7.3	141	183
CDC Orion	54.43	9.50	22.83	45.99	8.01	25.03	9.61	10.8	119	160
HB-14**	52.32	8.37	20.70	45.67	8.44	25.97	8.51	8.3	126	183
Sawyer**	52.80	8.81	21.53	44.30	8.43	25.23	9.33	8.3	123	181
Sierra	55.29	7.54	19.88	45.54	7.40	23.96	10.87	9.4	125	176
Troy	62.70	5.19	15.85	46.74	8.24	25.67	19.00	14.0	119	155
Unknown	56.71	8.12	21.06	45.01	8.15	23.99	12.16	12.3	115	169

*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

water hydration capacity and swelling capacity outcomes. For example, CDC Frontier 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 5.56 and 19.00, with a mean value of 10.45 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 Troy cultivar after canning (Table 44). The substantial reduction in the L* value likely contributed the higher color difference value. The Billy Bean cultivar had the lowest color difference after canning.

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 2017 fall within the range of those reported in 2012-2016.

Table 45. Percent recommended daily allowance (RDA) of minerals in a 50 g (dry) serving of pulses based on 2017 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	17	28	13	11	15	3	16	21	7
Lentil	16	39	17	12	16	3	12	16	6
Chickpea	16	26	11	9	13	3	15	20	6

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

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Funding Support

- Northern Pulse Growers Association
- North Dakota State University Agriculture Experimental Station

Acknowledgements

The 2017 U.S. Pulse Quality team acknowledges support received from funding sources, and Deb Tanner for creating the print version of the report. Please direct questions, comments, suggestions, or requests for copies of this report to Dr. Clifford Hall (Clifford.hall@ndsu.edu) at North Dakota State University, Ms. Shannon Berndt (berndt@northernpulse.com) at Northern Pulse Growers Association, and Mr. Todd Scholz (scholz@pea-lentil. com) at the USA Dry Pea and Lentil Council.

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