2016 U.S. Pulse Quality Survey

NDSU NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

Northern Pulse Growers Association

USA Dry Pea & Lentil Council

Contents

Summary Points 3

2016 Overview and
Author's Comments 3

Pulse Production 5

Laboratory Methods Used to
Measure Pulse Quality 6

Dry Pea Quality Results 8

Lentil Quality Results........................18

Chickpea Quality Results 27

Faba Bean Quality Results...............32

Percentage Recommended
Daily Allowance 33

Pulse Quality Technical Team...........35

Support for Pulse Quality..................36

2016 Overview and Author's Comments

Summary Points

1. The 2016 pulse quality report represents the 9th variation of a pulse quality evaluation started by the Northern Crops Institute in 2008.
2. Data from approximately 170 samples received from major US pulse growing regions were evaluated.
3. A range of physical and nutritional parameters general define pulse quality. Similar proximate composition to that of the 2015 and 2011 crop years while starch properties mirrored pulses from the 2014 crop year. However, chickpea results tended to follow more closely to previous data compared to peas and lentils.
4. Faba bean quality on one sample was reported for the first time in the survey history.

This report provides a summary of the 2016 pulse crop quality for dry pea, lentil, chickpea and faba bean varieties grown commercially in the USA. The quality is grouped into three main categories, which include proximate composition, physical parameters and functional characteristics. Proximate quality parameters include ash, mineral, moisture, protein, and total starch content. Water hydration capacity, percentage unhydrated seeds, swelling capacity, cooked firmness, test weight, 1000 seed weight, and color represent the physical parameters. The starch pasting characteristics represent the functional characteristics of the pulses.

In 2016, a total of approximately 170 pulse samples were collected from the major US pulse growing regions. The seeds evaluated included 98 dry pea, 50 lentil, 18 chickpea and 1 faba bean, which were acquired from industry representatives in pulse growing areas in Idaho, North Dakota, Montana and Washington. According to the USDA National Agricultural Statistics Service, pulse harvested acreage and estimated total production was highest for the 2016 crop years compared to the 4 previous years. Pea and Lentil production was up significantly, with lentil acreage almost doubling that of 2015. Modest gains in harvested chickpea acres was observed in 2016.

Results from the proximate (i.e., moisture, protein, etc.) composition analyses indicates that the pea, and chickpea crops were similar to the 2014 and 2015 crop years. Lentil proximate composition was most similar to the lentils harvested in 2012 and 2014 crop years. Similar to the 2015 crop, the 2016 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. In general, all pulses had higher moisture contents in 2016 compared to their respective 5-year mean moisture values. The ash, protein and total starch contents were lower than the five-year average. However, within pulse categories some of the parameters were comparable to previous crops. 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 2016 are an excellent source of a wide range of mineral including iron (Fe), zinc (Zn), magnesium (Mg) and selenium (Se). The 2016 pulses provide in excess of 10% of the RDA for these minerals. Regardless of market class, dry peas from 2016 had similar magnesium levels compared to 2015, but higher than the previous four years (2011-2014). The calcium and phosphorus content of the peas from 2016 were higher than previous years, while potassium was lower than previous crops for the green market class. In contrast, the yellow pea market class had higher potassium contents than previous crops. The other minerals fell within the range of the previous crop years, except selenium, which was lower in 2016 compared to previous years. 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 observed. In general, the composition of individual minerals in the green and red market classes tended to be higher than in the Spanish Brown market class. The major minerals composition in chickpeas tended to be higher in 2016 than previous years. However, trace minerals tended to be lower in 2016 than previous years.

The physical parameters such as water hydration capacity, test weight, and color analysis of the 2016 had varying results compared to previous pulse crops. The test weight of dry peas, lentil and chickpeas were approximately that of the 5-year average while the 1000 seed weight was slightly higher for chickpeas. The water hydration capacities of dry peas and lentils were lower than the 5-year average while chickpea water hydration capacities were similar to the 5-year average. Swelling capacities of the lentils and chickpea were higher than values from 2014, but lower than their respective samples compared to 2015. The water hydration capacities in peas were lower in 2016 compared to values observed in 2014 and 2015. The color quality of the dry green peas from 2016 were comparable to the green peas from other year except in the lightness (L*) values. The lentil color quality from the 2016 crop tended to be similar to the previous crops except that the lightness value was lower. The redness value in the red lentils also was higher in the red lentils from 2016. Green lentils from 2016 had higher yellowness and lower greenness values than 2015. The 2016 chickpea crop had lightness color values lower than previous crop years. However, the redness and yellowness values were similar to chickpeas grown in 2015, which tended to be higher than chickpeas from 2012 and 2014.

The starch characteristics of peas from 2016, 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 green peas from 2016 had starch viscosity properties similar to peas from 2013 and 2014. The 2016 lentil crop had peak, hot paste and cold paste viscosities that were higher than the 5-year viscosities. However, starch characteristics of the green market class were closer to the 5-year mean viscosity values than the red market class. The 2016 chickpea crop had viscosity values that were comparable to the 4-year mean viscosity values.

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. A canning protocol was developed during the summer of 2016 and is currently being applied to the 2016 survey samples. Completion of a canning survey will be completed in late spring of 2017 and published as a supplemental report. 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,

Clifford Hall, Ph.D.
clifford.hall@ndsu.edu

Pulse Production

The Northern Plains region and Pacific Northwest are the largest pulse producing area within the USA. US pulse acreage in 2016 was 2,553,100 (USDA 2016; Table 1). This estimate is substantially more than previous pulse production. Total US pulse production in 2016 is estimated to be 2,069,089 Metric Tons (MT) (USDA 2016), which nearly doubles that of the 1,113,245 MT and 1,061,732 MT produced in 2015 and 2014, respectively.

The UDSA (2016) estimated that the harvested dry pea acreage was 1.3 million in 2016. This was up from 1,083,500 acres in 2015, 924,278 acres in 2014 and 856,501 acres in 2013 (Table 1). Significant acres of green pea were harvested from Northeastern Montana (Figure 1). Lentil acreage was 930,000 acres in 2016, which was up significantly from 476,000 in 2015 and 260,243 in 2014 (USDA; Table 1). Northeastern Montana and Northwestern North Dakota had significant lentil production (Figure 2). Lentil production was 564,087 MT in 2016, which was substantially higher than 276,225 MT in 2015, 151,248 MT in 2014, 284,332 MT in 2013 and 229,171 MT in 2012. Chickpea harvested acres was 321,100 in 2016 (Table 1). The acres were up moderately from the 203,100 in 2015, 202,253 acres in 2014 and 208,243 acres in 2013 (USDA 2016). Some counties in Idaho and Washington produced over 50,000 acres (Figure 3). Production was approximately 276,225 MT in 2016, which was up significantly from the 98,817 MT in 2015, 127,386 MT in 2014, and 145,636 MT in 2013.

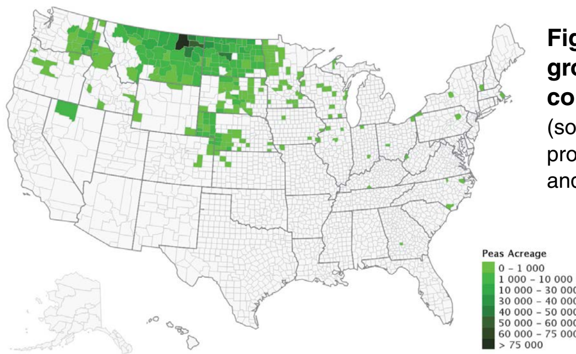


Figure 1. USA dry pea growing regions by county, 2016. (source USDA/FSA; provided by USA Dry Pea and Lentil Council)

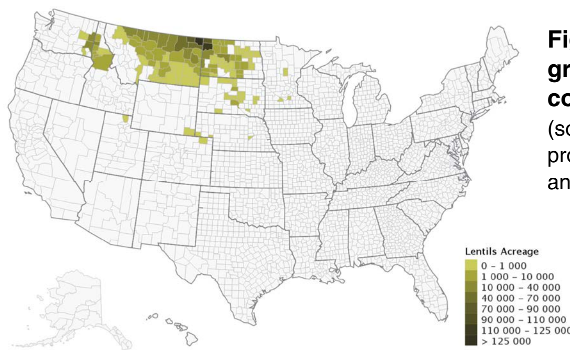


Figure 2. USA lentil growing regions by county, 2016. (source USDA/FSA; provided by USA Dry Pea and Lentil Council)

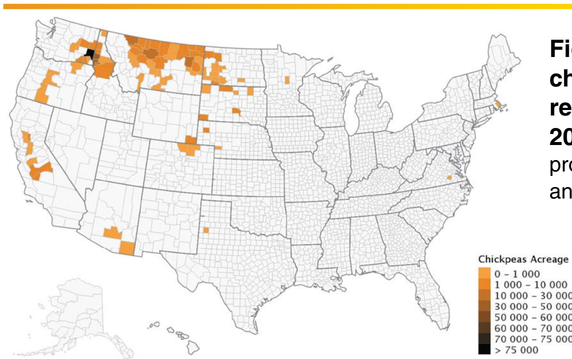


Figure 3. USA chickpea growing regions by county, 2016. (source USDA/FSA; provided by USA Dry Pea and Lentil Council)

Table 1. United states pulses acreage and production summary for 2012-2016.

	2016		2015		2014		2013		2012	
Crop	Acreage*	Production*	Acreage*	Production*	Acreage*	Production*	Acreage*	Production*	Acreage*	Production*
Dry Pea	1,302,000	1,228,282	1,083,500	738,203	924,278	783,098	856,501	833,841	639,972	535,299
Lentil	930,000	564,087	476,000	276,225	265,703	151,248	366,908	284,332	444,595	229,171
Chickpea	321,100	276,720	203,100	98,817	202,253	127,386	208,243	145,636	193,825	127,399
Total	**2,553,100**	**2,069,089**	**1,762,600**	**1,113,245**	**1,392,234**	**1,061,732**	**1,443,259**	**1,273,269**	**1,278,392**	**891,869**

*Acreage = Acres Harvested - USDA NASS (2016); Production = Metric Tons - U.S.A. Dry Pea and Lentil Council (2016).

Laboratory Methods Used to Measure Pulse Quality

Where applicable, standard methods were followed for the determination of each pulse quality attribute in 2016 (Table 2). The 2016 report includes updated changes in terminology from previous reports to better reflect the terminology used in the standard methods. Reports prior to 2014 included the terms water absorption and unsoaked seed to describe water absorption by the pulses. The standard methods (AACC International Method 56-35.01) use the terms water hydration capacity and percentage unhydrated seeds, respectively, to describe water absorption by the pulse and the amount of seeds that are not fully hydrated after a 16 to 24-hour soak. Swelling capacity and color difference between soaked and non-soaked pulses are included in the 2016 report as is cooking firmness. 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 chick peas 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 the brown pulses has 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 2016 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. Minerals	Thavarajah et al., 2008, 2009	Indicator of nutritional quality as related to specific minerals.
6. Test weight (lb/bu)	AACC International method 55-10	Indicator of sample density, size, and shape.
7. 1000 seed weight (g)	100-kernel sample weight times 10	Indicator of grain size and milling yield.
8. Water hydration capacity (%)	AACC International method 56-35.01	Indicator of cooking and canning behavior.
9. Unhydrated seed (%)	AACC International method 56-35.01	Indicator of cooking and canning behavior and the amount of seed that may not rehydrate.
10. 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.
11. 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.
12. Color difference (ΔE*ab)	The color difference between the dried (pre-soaked) and the soaked pulse was determined using L*, a and b values from the color analysis as follows (Minolta): $\Delta E^*ab = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$	Indicator of general color difference between pre- and post-soaked pulses. The lower the value, the more stable is the color.
13. 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.
14. 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.

Dry Pea Quality Results

Sample distribution

A total of 98 dry pea samples were collected from Idaho, Minnesota, Montana, North Dakota and Washington from August to November 2016. Samples were delivered to NDSU between September and December 2016. 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. Green peas accounted for 41 of the samples collected, where Banner (5), Greenwood (8) and Shamrock (5), made up for the majority of the green peas evaluated. The remaining samples were a mix of various cultivars (Table 3). Yellow peas accounted for 47 of the pea samples collected where Agassiz (10) and Jetset (7) 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 yellow pea samples were not identified.

Table 3. Description of dry pea samples used in the 2016 pulse quality survey.

State	No. of samples	Market class	Cultivars	
Minnesota	2	Yellow	Agassiz	Jetset
Montana	13	Green	Ariel CDC Striker Ginny	Greenwood Majoret Shamrock
		Yellow	AC Earlystar	CDC Meadows
North Dakota	65	Green	Arcadia Blue Moon CDC Raezer CDC Striker Columbian	Daytona Greenwood Majoret Shamrock Viper
		Yellow	AAC Carver Abarth AC Earlystar Admiral Agassiz Bridger	CDC Meadows Durwood Jetset Leroy Mystique Nette
Washington/ Idaho/Oregon	18	Green	Aragorn Ariel Banner	Ginny Greenwood
		Yellow	Carousel	Universal

Proximate composition of dry pea (Tables 4-6)

Moisture

The moisture content of dry pea ranged from 7.8-13.0% in 2016 (Table 4). The mean moisture content of all 98 pea samples was 10.1%, which is higher than the 5-year mean of 9%. Dry peas grown in 2016 had moisture contents similar to pea samples from the 2012, 2014 and 2015 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 approximately the same (Table 5). The green and yellow seed moisture of 9.6 and 10.5%, respectively, were higher than the 5-year mean values of 8 and 9%, respectively. The highest moisture contents were observed in the Daytona cultivar (i.e. green pea) and the Abarth cultivar in the yellow market class (Table 6). However, most of the peas had moisture contents between 10 and 11% 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, 2011-2016.

Proximate Composition (%)*	2016		Mean					5-year
	Range	Mean (SD)	2015	2014	2013	2012	2011	Mean (SD)
Moisture	7.8-13.0	10.1 (1.0)	11	11	6	9	7	9 (2)
Ash	1.9-3.1	2.5 (0.2)	2.5	2.3	2.5	2.6	2.6	2.5 (0.1)
Protein	16.0-24.9	20.8 (1.6)	20	23	25	25	23	23 (2)
Total Starch	35.4-54.8	42.8 (3.1)	42	44	52	52	41	46 (5)

*composition is on an "as is" basis

Table 5. Proximate composition of different market classes of dry peas grown in the USA, 2011-2016.

Proximate Composition (%)*	Mean (SD) of green pea						5-year Mean (SD)
	2016	2015	2014	2013	2012	2011	
Moisture	9.6 (0.9)	10 (1)	11 (1)	5 (3)	9 (0.7)	7 (0.4)	8 (2)
Ash	2.4 (0.2)	2.5 (0.2)	2.3 (0.2)	2.5 (0.1)	2.7 (0.2)	2.6 (0.2)	2.5 (0.1)
Protein	21.0 (1.8)	21 (2)	23 (1)	23 (3)	25 (3)	22 (2)	23 (1)
Total Starch	42.1 (2.9)	41 (3)	44 (2)	52 (7)	53 (6)	40 (6)	46 (6)
Starch Characteristics	**Mean (SD) of yellow pea**						**5-year Mean (SD)**
	2016	**2015**	**2014**	**2013**	**2012**	**2011**	
Moisture	10.5 (0.9)	11.5 (1.1)	12 (1)	7 (3)	9 (0.6)	7 (0.1)	9 (2)
Ash	2.6 (0.2)	2.4 (0.2)	2.4 (0.1)	2.4 (0.1)	2.6 (0.2)	2.7 (0.2)	2.5 (0.1)
Protein	20.6 (1.5)	19.9 (1.7)	22 (1)	23 (4)	25 (1)	23 (2)	23 (2)
Total Starch	43.3 (3.2)	41.2 (4.7)	43 (1)	52 (6)	50 (8)	44 (4)	46 (5)

*composition is on an "as is" basis

Table 6. Mean proximate composition of dry pea cultivars grown in the USA in 2016.

Market Class	Cultivar	Concentration (%)			
		Moisture	Ash	Protein	Starch
Green	Aragorn**	8.9	2.3	22.5	46.2
	Arcadia	10.4	2.4	20.6	43.7
	Ariel	9.5	2.5	21.7	39.6
	Banner	8.7	2.3	19.6	40.4
	Blue Moon**	10.7	2.6	22.8	39.4
	CDC Raezer**	10.2	2.6	20.5	41.5
	CDC Striker	10.2	2.4	21.1	41.6
	Columbian**	9.3	2.6	24.9	43.1
	Daytona	11.6	2.4	21.4	39.1
	Ginny	8.9	2.3	20.0	41.6
	Greenwood	9.1	2.5	20.7	42.9
	Majoret	9.5	2.6	19.1	49.3
	Shamrock	10.0	2.5	22.3	40.8
	Viper	9.8	2.5	21.0	47.0
Yellow	AAC Carver**	10.7	2.5	20.3	44.4
	Abarth**	11.6	2.7	17.3	47.2
	AC Earlystar	11.2	2.4	20.0	42.2
	Admiral**	9.9	2.6	22.0	45.4
	Agassiz	10.7	2.6	20.3	42.5
	Bridger**	10.5	2.5	20.4	42.7
	Carousel**	8.6	2.4	20.1	45.0
	CDC Meadows	9.8	2.4	18.8	44.2
	Durwood**	10.5	2.5	21.9	41.7
	Jetset	11.3	2.6	21.3	41.0
	Leroy**	9.6	2.6	21.5	41.6
	Mystique	10.5	3.0	21.5	45.2
	Nette**	10.0	2.6	17.8	42.3
	Universal**	9.7	2.3	20.3	40.5
	Unknown	10.2	2.5	20.8	43.9

**Only one sample of cultivar tested

Ash

Ash content of dry pea ranged from 1.9-3.1%, with a mean of 2.5%. The mean ash content of dry peas grown in 2016 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 approximately the same (Table 5). The yellow and green pea ash contents of 2.4 and 2.6%, respectively, were similar to the 5-year mean value of 2.5%. Little variability in ash contents were observed among cultivar (Table 6). This suggests that total mineral consumption between cultivars is essentially the same. However, Mystique of the yellow market class had the highest ash content at 3.0%. Aragorn, Ginny and Universal had the lowest (2.3%) ash contents (Table 6).

Protein

Protein content of dry pea ranged from 16-25% with a mean of 21%. The mean protein content was one percentage point higher than peas from the 2015 crop year. The mean protein content of dry peas grown in 2016 was lower than the 5-year mean of 23%. This difference likely would not affect handling and processing of the peas. Although, protein isolation might be affected slightly.

The protein contents of the green and yellow market classes were approximately the same (Table 5). Yellow peas had a mean protein content (20.6%) that was lower than the 5-year mean value of 23 %. Although the green peas from 2016 had lower protein compared to 5-year mean value (21% vs. 23%), protein content of green peas harvested in 2016 were comparable to those obtained from the 2011 and 2015 harvest years. The Admiral, Durwood and Leroy (yellow) and Columbian (green) cultivars had the highest protein contents in their respective market classes (Table 6). In contrast, Abarth (Yellow) and Majoret (green) had the lowest (17 and 19%) protein contents among their respective market classes.

Total starch

Total starch content of dry pea ranged from 35-55% with a mean of 42.8%. The mean total starch content of dry peas grown in 2016 was comparable to dry peas from the 2014 and 2015 harvest years (i.e. 42-44%), but lower than the 5-year mean of 46%.

The starch contents of the green and yellow market classes were approximately 42 and 43%, respectively (Table 5). Green peas had a mean starch content (42.1%) 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 (43.3%), the mean starch content of yellow peas harvested in 2016 was higher than the green peas obtained from the 2011 and 2015 harvest years. Majoret had the highest (49.3%) starch content among the green peas while Daytona had the lowest (39.1%) starch content. Abarth had the highest mean starch content (47.2%) and Universal the lowest (40%) among the yellow pea cultivars (Table 6).

Mineral composition of dry pea (Tables 7-8)

Mineral composition varies the most among the proximate chemical components tested in 2016. The mean calcium content for all pea samples was 576 mg/kg with a range in values of 398 to 825 mg/kg. Iron content ranged from 30 to 77 mg/kg with a mean value of 45 mg/kg. Selenium mean content was 188 mg/kg with a range in values of 123 to 290 µg/kg. The variability in mineral content is further illustrated by the range in potassium (4892 to 8088 mg/kg) and phosphorus (2464 to 6811 mg/kg) contents. The variability in minerals likely relates to the soil in which the pulse is grown. Similar to 2015, sample obtained in 2016 were from many growing regions and that may have impacted mineral composition. Potassium and phosphorus account for the highest amounts of miner-

Table 7. Mineral concentrations of dry peas grown in the USA, 2011-2016.

Micronutrient (mg/kg)	Mean (SD) of green pea						5-year Mean
	2016	2015	2014	2013	2012	2011	
Calcium	552 (82)	534 (91)	554 (106)	333 (169)	345 (167)	507 (114)	455
Copper	6 (1)	5 (1)	6 (1)	6 (2)	*	*	6**
Iron	45 (6)	44 (7)	42 (6)	41 (14)	41 (9)	39 (6)	41
Magnesium	1224 (106)	1280 (82)	813 (41)	689 (242)	440 (98)	769 (58)	798
Manganese	10 (2)	9 (1)	9(2)	11 (4)	*	*	10**
Potassium	5781 (448)	6709 (662)	8801 (715)	7529 (1801)	9004 (601)	6000 (320)	7609
Phosphorus	3792 (810)	3179 (404)	2583 (326)	2902 (1190)	3242 (283)	*	2977**
Zinc	24 (4)	24 (4)	32 (7)	38 (6)	25 (4)	8 (0)	25
Selenium (µg/kg)	176 (29)	151 (49)	369 (65)	300 (300)	600 (500)	326 (288)	349

Micronutrient (mg/kg)	Mean (SD) of yellow pea						5-year Mean (SD)
	2016	2015	2014	2013	2012	2011	
Calcium	593 (87)	571 (114)	599 (119)	494 (173)	390 (99)	529 (68)	517
Copper	6 (1)	5 (1)	6 (1)	5 (2)	4 (2)	8 (1)	6
Iron	45 (7)	38 (5)	42 (7)	36 (13)	50 (10)	42 (7)	42
Magnesium	1351 (88)	1319 (80)	817 (111)	728 (182)	579 (68)	821 (35)	853
Manganese	11 (2)	8 (2)	10 (2)	11 (3)	10 (3)	12 (2)	10
Potassium	6441 (508)	6168 (594)	8056 (2271)	6335 (1477)	7490 (743)	5830 (312)	6776
Phosphorus	4695 (981)	2912 (307)	2522 (395)	2223 (869)	2860 (319)	*	2629**
Zinc	24 (4)	21 (3)	32 (7)	29 (8)	35 (7)	22 (3)	28
Selenium (µg/kg)	197 (31)	200 (47)	365 (125)	500 (300)	500 (300)	700 (400)	453

*data not reported; **3- or 4-year mean

als in the pea samples regardless of market class (Table 7). The potassium content of green peas from 2016 was lower than the previous crop years. In contrast, yellow peas from 2016 had mean potassium levels higher than previous crop years except 2012 and 2014. Phosphorus content in both green and yellow peas was higher than samples from the five previous years. Calcium was higher in peas grown in 2016 compared to the previous years except 2014 (Table 7). Magnesium composition in both green and yellow peas from 2016 was comparable to pea samples from 2015 and higher than the 2011-2014 harvest years. The trace minerals (copper, iron, manganese and zinc) of peas harvested in 2016 were varied from those of the previous 4 harvest years (Table 7). Iron content was higher in both green and yellow peas compared to the 5-year mean values. Manganese and zinc in peas tended to be similar to previous years except 2013 and 2014 (Table 7). Mean selenium (another trace mineral) contents of yellow and green peas grown in 2016 was comparable to peas from 2015, but significantly lower than the mean selenium contents from 2011-2014 (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 461 mg/kg in CDC Raezer to 707 mg/kg in Daytona while the calcium content varied from 398 mg/kg to 825 mg/kg in Abarth and Leroy yellow pea cultivars, respectively. Potassium content in Mystique and CDC Raezer were highest (6844 and 6769 mg/kg) among the yellow and green pea cultivars, respectively, while Universal and Majoret had the lowest (5128 and 5277 mg/kg) potassium contents among yellow and green pea cultivars, respectively. Similar variability existed in the trace minerals, but to a lesser degree (Table 8). The emphasis on soil mineral composition is important as soil mineral content often is indicative of mineral composition in the plant.

Table 8. Mean mineral concentrations of dry pea cultivars grown in the USA in 2016.

Market Class	Cultivar	Concentration (mg/kg)* Ca	Cu	Fe	K	Mg	Mn	P	Zn	(µg/kg) Se
Green	Aragorn**	618	6	46	5308	1188	10	3192	24	172
	Arcadia	604	6	40	5968	1290	10	4491	23	187
	Ariel	587	6	45	5499	1162	9	3748	21	161
	Banner	516	6	46	5549	1148	9	3149	19	144
	Blue Moon**	516	8	50	5563	1122	10	3682	30	172
	CDC Raezer**	461	6	45	6769	1337	11	4324	27	191
	CDC Striker	544	7	42	5831	1275	9	4019	27	196
	Columbian**	667	7	52	6112	1218	10	3108	24	151
	Daytona	707	6	54	6428	1523	13	3881	23	179
	Ginny	567.1072653	6	43	5683	1210	10	3362	24	169
	Greenwood	527.1686736	6	44	5897	1198	10	3967	24	171
	Majoret	539.4176994	6	42	5277	1248	8	3353	26	207
	Shamrock	523.8929857	6	48	5734	1177	10	3565	25	195
	Viper	522	6	47	5987	1302	9	5627	25	190
Yellow	AAC Carver**	688	5	44	5963	1432	12	4270	26	196
	Abarth**	398	5	43	6916	1312	10	5312	19	229
	AC Earlystar	540	6	41	6340	1374	15	3748	24	203
	Admiral**	671	6	38	6174	1359	10	6514	23	188
	Agassiz	600	7	51	6750	1441	12	4322	24	204
	Bridger**	527	5	41	6736	1274	8	4723	20	250
	Carousel**	508	6	50	5726	1127	10	2891	24	141
	CDC Meadows	512	7	45	6431	1360	11	4643	25	186
	Durwood**	693	6	51	6540	1446	10	5515	31	196
	Jetset	634	6	42	6534	1390	10	3713	24	196
	Leroy**	825	8	54	5849	1378	12	4853	33	200
	Mystique	600	6	45	6844	1378	10	4679	26	189
	Nette**	617	6	37	6373	1377	11	4837	17	226
	Universal**	633	5	40	5128	1178	9	2915	24	143
	Unknown	579	6	43	6330	1301	10	5332	22	195

*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 32-77 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 2016 was comparable to those from 2013 to 2015. The test weights of peas in the yellow and green market classes were the same (63 lbs/bu). The test weight of individual cultivars were comparable to one another and fell within the range of 60 to 65 lbs/bu (Table 11). The only exceptions were the 55 and 67 lbs/bu for the Banner and Columbian cultivars, respectively.

The range and mean **1000 seed weight** of dry peas grown in 2016 were 150-307 g and 224 g, respectively (Table 9). The mean value (224 g) was significantly higher than the mean 1000 seed weights of peas evaluated in the 2011 and 2012 harvest years. Furthermore, peas from 2016 had a mean 1000 seed weight value that was slightly higher than the 5-year mean of 218 g. Peas of the green market class had a mean 1000 seed weight of 213 g, which is higher than the 5-year mean value of 207 g. In contrast, peas of the yellow market class had a mean 1000 seed weight of 231 g, which is higher than the 5-year mean (221 g) and the 1000 mean weights of the green peas (Table 10). The individual cultivars (Table 11) varied extensively in 1000 seed weight, where the cultivars in the green market class varied (184 to 301 g) more than cultivars in the yellow market class (184 to 253 g). Columbian and Daytona and Leroy and Jetset 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 measuring water hydration capacity, percentage of unhydrated seeds and swelling capacity. **Water hydration**

Table 9. Physical parameters of dry peas grown in the USA, 2011-2016.

Physical Parameter	Year							5-year Mean
	2016		2015	2014	2013	2012	2011	
	Range	Mean (SD)	Mean	Mean	Mean	Mean	Mean	
Test Weight (lb/bu)	32-77	63 (4)	64	63	64	61	61	63 (2)
1000 Seed Wt (g)	150-307	224 (29)	215	216	222	206	203	212 (8)
Water Hydration Capacity (%)	79-114	97 (6)	111	102	98	103	101	103 (5)
Unhydrated Seeds (%)	0-18	2 (3)	2	2	8	0.8	0.6	3 (3)
Swelling Capacity (%)	98-183	137 (16)	145	152	*	*	*	nd
Cooked Firmness (N/g)	12.2-34.0	22.5 (5)	21	*	*	*	*	nd

*data not reported; nd = not determined

Table 10. Physical parameters of different market classes of dry peas grown in the USA, 2011-2016.

Physical Parameter	Mean (SD) of green pea						5-year Mean (SD)
	2016	2015	2014	2013	2012	2011	
Test Weight (lb/bu)	63 (6)	63 (2)	63 (2)	63 (2)	62 (1)	61 (1)	62 (1)
1000 Seed Wt (g)	213 (29)	207 (43)	219 (21)	212 (29)	201 (31)	195 (22)	207 (9)
Water Hydration Capacity (%)	100 (6)	114 (11)	100 (6)	102 (14)	104 (5)	101 (4)	104 (6)
Unhydrated Seeds (%)	1 (1)	2 (2)	1.0 (1)	8 (9)	0.5 (1)	0.5 (1)	3 (3)
Swelling Capacity (%)	140 (16)	142 (23)	150 (13)	*	*	*	nd
Cooked Firmness (N/g)	23 (5)	17 (5)	*	*	*	*	nd

Physical Parameter	Mean (SD) of yellow pea						5-year Mean (SD)
	2016	2015	2014	2013	2012	2011	
Test Weight (lb/bu)	63 (2)	64 (1)	62 (2)	64 (2)	62 (2)	62 (1)	63 (1)
1000 Seed Wt (g)	231 (27)	220 (32)	211 (38)	235 (29)	212 (23)	225 (22)	221 (10)
Water Hydration Capacity (%)	95 (6)	110 (18)	99 (13)	94 (11)	102 (8)	99 (4)	101 (6)
Unhydrated Seeds (%)	2 (4)	2 (2)	2.0 (2)	8 (9)	2 (3)	1 (1)	3 (3)
Swelling Capacity (%)	135 (16)	147 (14)	149 (13)	*	*	*	nd
Cooked Firmness (N/g)	22 (5)	22 (6)	*	*	*	*	nd

*data not reported; nd = not determined

capacity of dry peas ranged from 79 to 114%, with a mean of 97% (Table 9). The 2016 mean value is slightly lower than the 5-year mean of 103%. Peas from individual harvest years had slightly higher hydration capacity compared to 2016 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 peas from 2016 had hydration capacities similar to the peas from the 2013 harvest year and slightly lower values in 2011 and 2014. The water hydration capacity ranged from 79% in Nette (yellow) to 100% in Agassiz (yellow) cultivars (Table 11). In the green market class, CDC Striker and Shamrock had the lowest (93%) and highest (106%) water hydration capacities, respectively.

Unhydrated seed percentage ranged from 0-18% 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 seeds values of 1% while samples in the yellow market class had varying unhydrated seed numbers (Tables 10 and 11). However, both market classes had fewer unhydrated seeds in 2016 compared to the 5-year average and values from 2013 (Table 10). The majority of the green pea cultivars had unhydrated seed rates of 0 or 1% while CDC Meadows and Nette had unhydrated seed rates of 7 and 18% (Table 11). These 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 98 to 183% with a mean value of 137% (Table 9). The mean swelling capacity for peas from the 2016 harvest was slightly lower than the 2015 and 2014 harvest years. The swelling

Table 11. Mean physical parameters of USA dry pea cultivars grown in 2016.

Market Class	Cultivar	Test Weight (lb/bu)	1000 Seed Wt (g)	Water Hydration Capacity (%)	Unhydrated Seeds (%)	Swelling Capacity (%)	Cooked Firmness (N/g)
Green	Aragorn**	61	247	97	0	120	28.8
	Arcadia	65	209	96	0	135	27.2
	Ariel	62	185	103	0	136	22.7
	Banner	55	205	99	1	140	23.9
	Blue Moon**	63	234	103	2	147	20.8
	CDC Raezer**	63	257	96	0	118	21.7
	CDC Striker	63	202	90	0	125	21.5
	Columbian**	77	184	104	0	134	21.4
	Daytona	65	301	93	0	124	30.9
	Ginny	63	209	101	1	141	23.8
	Greenwood	64	196	103	1	150	22.7
	Majoret	63	218	98	1	136	29.0
	Shamrock	64	224	106	1	158	20.7
	Viper	61	238	99	1	143	20.1
Yellow	AAC Carver**	65	237	99	0	137	23.6
	Abarth**	62	247	87	4	158	17.8
	AC Earlystar	63	242	95	1	138	20.7
	Admiral**	63	244	93	3	134	17.8
	Agassiz	62	241	100	0	140	19.0
	Bridger**	65	209	99	1	138	23.0
	Carousel**	63	239	98	2	133	26.2
	CDC Meadows	63	223	94	7	137	19.4
	Durwood**	60	221	98	0	126	25.4
	Jetset	62	253	96	1	134	23.3
	Leroy**	64	184	97	0	133	19.7
	Mystique	63	205	99	4	154	16.7
	Nette**	64	235	79	18	137	21.4
	Universal**	63	234	97	0	118	26.3
	Unknown	64	226	92	3	129	24.0

**Only one sample of cultivar tested

capacity of green peas was about 5% points higher than the yellow pea market class (Table 10). Variability in the swelling capacity among cultivar was observed (Table 11). Shamrock (green) and Abarth (yellow) had the greatest swelling capacity while CDC Raezer (green) and Universal (yellow) had the lowest swelling capacity among the cultivars tested (Table 11).

The **cooked firmness** was completed for the second time in 2016. The larger the number, the firmer is the cooked pea. The cooked firmness for all peas ranged from 12 to 34 N/g with a mean value of 23 N/g (Table 9). The cooked firmness of peas was not significantly different between market classes (Table 10). The green peas had firmness values that were five percentage points higher than those from the 2015 green peas. In contrast, the cooked firmness values in yellow peas were the same between 2015 and 2016. Among the green cultivars, Viper had the lowest cooking firmness while Daytona was the firmest (Table 11). For yellow cultivars, Universal had the highest cooking firmness (i.e. most firm) among the cultivars tested while Mystique the lowest cooked firmness (Table 11).

Color is an important quality attribute for the dry pea food industry. 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 2016 indicated that the peas had lower L* values than any other crop year since 2011 (Table 12). This observation was true for both green and yellow peas. This data indicates that the peas from the 2016 crop year were darker in color than those from previous years. The less negative value for red-green (i.e., “a” value) value in 2016 indicates a less green color than 2012-2015. However, the green peas from 2011 were had similar green color based on a similar negative “a” value to peas from 2016 (Table 12). The “b” value for green peas from 2016 was similar to peas from 2015 and 2013 and indicate a less blue color compared to the peas from 2011, 2012 and 2014. The higher “b” values combined with the “a” value on the green part of the scale (i.e. negative number) indicates that the samples would be 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 2016 appear light green in color compared to those from 2014. However, this observation is true for the general crop as a whole. Specific varieties may appear more or less green than others within the specific market class. For the yellow pea market class, the 2016 crop had similar lightness values to peas from 2011, 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 2016 had “a” values that were the same as the 2013 and 2015 crops, but more red in color to the peas from 2014, 2012 and 2011. 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 lighter yellow in color, as in the case of the 2016 crop. The lower “a” combined with a lower “b” values indicates that the pulses would be a darker yellow color. Therefore, the yellow peas in 2016 appear light yellow compared to peas from 2011, 2012 and 2014. However, the peas from

Table 12. Color quality of dry peas grown in the USA before and after soaking, 2011-2016.

	Mean (SD) of green pea											
	Before soaking						After soaking					
Color Scale*	2016	2015	2014	2013	2012	2011	2016	2015	2014	2013	2012	2011
L (lightness)	52.01 (2.47)	62.32 (4.11)	61.99 (2.19)	66 (8)	60 (2)	61 (2)	46.86 (2.68)	57.83 (4.27)	55.12 (2.58)	59 (9)	54 (2)	55 (2)
a (red-green)	-0.98 0.86	-3.53 (1.48)	-2.10 (0.89)	-3.8 (1)	-1.9 (1)	-0.9 (3)	-5.14 (1.18)	-9.07 (3.87)	-7.95 (2.56)	-15 (4)	-8.4 (1)	-8.7 (1)
b (yellow-blue)	14.01 (1.26)	15.31 (1.52)	8.79 (0.84)	14 (2)	9 (1)	10 (2)	27.39 (1.82)	22.57 (6.28)	18.73 (2.56)	34 (4)	18 (1)	18 (1)
Color Difference	15.17 (2.02)	11.44 (5.34)	13.43 (1.15)	**	**	**						

	Mean (SD) of yellow pea											
	Before soaking						After soaking					
Color Scale	2016	2015	2014	2013	2012	2011	2016	2015	2014	2013	2012	2011
L (lightness)	57.29 (2.52)	71.33 (1.87)	65.83 (0.98)	71 (8)	65 (2)	65 (2)	69.51 (1.71)	68.00 (3.78)	64.76 (1.47)	77 (14)	65 (1)	66 (2)
a (red-green)	7.16 (0.84)	6.51 (0.79)	4.64 (0.43)	7.0 (1)	4.7 (1)	4.7 (0.3)	9.62 (0.90)	4.65 (1.73)	4.57 (0.33)	6.3 (5)	5.4 (1)	5.6 (1)
b (yellow-blue)	19.35 (1.37)	21.99 (2.23)	13.51 (1.20)	21 (2)	14 (1)	14 (0.4)	36.70 (2.55)	27.56 (5.19)	26.50 (3.36)	47 (6)	30 (1)	30 (0.4)
Color Difference	19.96 (2.52)	8.41 (5.24)	13.04 (2.37)	**	**	**						

*color scale: L (lightness) axis – 0 is black and 100 is white; a (red-green) axis – positive values are red, negative values are green, and zero is neutral; and b (yellow-blue) axis – positive values are yellow, negative values are blue, and zero is neutral.
**data not reported; color difference = change in value before soaking and after soaking

2016 would be similar in appearance to the peas from 2013 and 2015.

The color of the dry peas changed after the soaking process. The change in color was greater for peas from the 2016 crop year compared to 2014 and 2015 (Table 12). The green peas became darker (lower L*) while the "a" value became more negative (i.e., greener), but more yellow (i.e., increased "b" value). This same trend occurred in the 2011-2015 crop years. In 2016, lightness increased after soaking of the yellow peas. This is opposite of the decrease in lightness observed in yellow peas from 2014 and 2015. In addition, soaking decreased the greenness (i.e. "a" values) and increased yellowness (i.e. "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 2016 were greater than those previously reported.

Similar to 2015, the Shamrock cultivar from 2016 had the lowest L* values, the lowest "a" value and the highest "b" value, which produced an intense green color. Majoret and Viper had the highest L and "b" values and least negative "a" values resulting in a light green colored pea. 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 Ara-

Table 13. Color quality of USA dry pea cultivars before and after soaking, 2016.

Market Class	Cultivar	Mean Color Values*						
		Before Soaking			After Soaking			Color Difference
		L	a	b	L	a	b	
Green	Aragorn**	52.96	-0.91	12.18	44.36	-6.61	26.31	17.56
	Arcadia	53.88	-1.16	13.94	49.98	-5.08	25.74	13.10
	Ariel	53.35	-0.80	12.49	46.70	-5.52	26.04	16.09
	Banner	50.40	-1.04	14.13	45.28	-5.04	26.97	14.60
	Blue Moon**	50.81	-0.66	14.27	47.89	-4.87	27.10	13.81
	CDC Raezer**	53.39	-0.46	13.64	48.76	-5.43	29.09	16.92
	CDC Striker	54.64	-0.27	13.28	50.09	-4.08	25.48	13.90
	Columbian**	53.24	-1.07	15.28	46.16	-5.57	28.00	15.44
	Daytona	51.63	-0.62	13.85	48.68	-3.64	28.70	15.58
	Ginny	53.84	-1.08	13.01	46.91	-5.73	27.33	16.70
	Greenwood	50.38	-1.49	14.04	44.45	-5.91	28.77	16.61
	Majoret	55.33	-0.84	13.75	50.56	-4.77	25.86	13.84
	Shamrock	48.23	-1.89	16.39	44.94	-5.53	28.90	13.72
	Viper	55.34	1.05	14.52	50.54	-2.71	27.26	14.38
Yellow	AAC Carver**	58.74	7.51	18.86	59.46	10.98	39.71	21.18
	Abarth**	53.68	8.34	20.35	56.35	10.57	39.27	19.32
	AC Earlystar	58.21	7.40	20.70	60.83	10.32	40.30	20.21
	Admiral**	55.98	7.11	18.35	57.55	11.12	34.07	16.31
	Agassiz	58.03	6.70	18.43	60.64	8.82	35.94	18.15
	Bridger**	60.06	7.86	19.77	58.90	10.76	34.97	15.54
	Carousel**	57.92	7.14	18.14	52.90	9.38	36.02	18.80
	CDC Meadows	57.96	7.04	20.11	60.72	9.81	40.33	20.63
	Durwood**	57.85	5.67	17.96	58.80	10.55	35.48	18.21
	Jetset	53.69	7.13	18.88	60.54	9.82	38.06	20.77
	Leroy**	56.91	6.28	19.11	57.05	10.98	40.11	21.54
	Mystique	57.60	8.08	19.45	60.09	9.99	35.85	16.90
	Nette**	55.05	7.90	21.35	60.37	7.72	36.38	15.95
	Universal**	58.29	5.94	17.06	59.94	9.33	36.06	19.45
	Unknown	57.91	7.22	19.79	58.93	9.53	35.88	16.42

*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

gorn cultivar. The green (more negative "a" value) color change was noticeable. The cultivars of the yellow peas had L* values between 53.68 and 60.06, with Bridger being the lightest and Abarth and Jetset the darkest. Carousel retained the darkest color after soaking while AC Earlystar became the lightest. Abarth had the highest redness ("a" value) score while the lowest was recorded for the Durwood cultivar (Table 13). After soaking, Nette and DS Admiral had the lowest and highest redness scores, respectively. The yellowness of the dry yellow peas was greatest for Nette and lowest for Universal. After soaking, AC Earlystar and CDC Meadows had the highest yellowness values while DS Admiral had the lowest. The greatest color difference was observed in the Leroy cultivar. The increase in redness and yellowness during soaking likely contributed to the greatest color difference.

Starch Properties (Tables 14-16)

The peas from 2016 had peak viscosity, hot and cold paste viscosities and setback values that were nearly identical to peas from 2014 and were similar to the 5-year average, but lower than the values of peas from 2011(Table 14). Mean peak time was slightly less than the 5-year mean value. Pasting temperature ranged from 50-80 °C, with a mean of 76°C. The mean value is comparable to from previous years. The starch characteristics were similar between the green and yellow pea market classes. Pea flour peak viscosities of 147 and 145 RVU were recorded for the green and yellow market classes, respectively (Table

Table 14. Starch characteristics of dry peas grown in the USA, 2011-2016.

Starch Characteristic	2016 Range	2016 Mean (SD)	2015 Mean	2014 Mean	2013 Mean	2012 Mean	2011 Mean	5-year Mean (SD)
Peak Viscosity (RVU)	84-225	146 25)	136	143	141	123	215	152 (36)
Hot Paste Viscosity (RVU)	81-183	132 (18)	127	133	122	117	165	133 (19)
Breakdown (RVU)	1-49	14 (10)	8	10	20	6	41	17 (14)
Cold Paste Viscosity (RVU)	121-454	251 (58)	229	248	212	213	355	251 (60)
Setback (RVU)	41-271	119 (4)	102	115	91	96	200	121 (45)
Peak Time (Minute)	4-7	5 (1)	5	6	8	9	8	7 (2)
Pasting Temperature (°C)	50-80	76 (3)	77	78	*	*	*	*

*data not reported

Table 10. Physical parameters of different market classes of dry peas grown in the USA, 2011-2016.

Starch Characteristic	Mean (SD) of green pea 2016	2015	2014	2013	2012	2011	5-year Mean (SD)
Peak Viscosity (RVU)	147 (23)	129 (19)	144 (25)	146 (17)	120 (12)	223 (120)	152 (41)
Hot Paste Viscosity (RVU)	131 (18)	122 (17)	135 (20)	122 (9)	115 (10)	169 (62)	133 (22)
Breakdown (RVU)	15 (9)	6 (5)	9 (7)	24 (15)	5 (5)	41 (13)	17 (15)
Cold Paste Viscosity (RVU)	253 (58)	219 (41)	252 (43)	218 (27)	215 (31)	365 (72)	254 (64)
Setback (RVU)	122 (43)	97 (25)	118 (26)	96 (23)	100 (22)	209 (57)	124 (48)
Peak Time (Minute)	5 (1)	6 (1)	6 (1)	8 (0.3)	9 (2)	8 (0)	7 (1)
Pasting Temperature (°C)	76 (2)	78 (2)	78 (1)	*	*	*	nd

Starch Characteristic	Mean (SD) of yellow pea 2016	2015	2014	2013	2012	2011	5-year Mean (SD)
Peak Viscosity (RVU)	145 (27)	140 (19)	140 (26)	136 (19)	126 (17)	192 (14)	147 (26)
Hot Paste Viscosity (RVU)	132 (19)	130 (15)	128 (18)	122 (19)	119 (11)	152 (12)	130 (13)
Breakdown (RVU)	13 (10)	10 (5)	12 (10)	17 (11)	8 (8)	41 (5)	18 (14)
Cold Paste Viscosity (RVU)	249 (60)	234 (39)	237 (45)	207 (42)	211 (38)	331 (33)	244 (50)
Setback (RVU)	117 (44)	104 (26)	108 (30)	85 (26)	93 (28)	179 (23)	114 (38)
Peak Time (Minute)	5 (1)	5 (1)	6 (1)	8 (0)	9 (1)	8 (0.2)	7 (2)
Pasting Temperature (°C)	75 (4)	76 (4)	77 (2)	*	*	*	nd

*data not reported; nd = not determined

15). Green peas from 2016 had slightly higher peak viscosities than the peas from 2012 and 2015 harvest years, but similar values to peas from 2013 and 2014. Hot and cold paste viscosities of green peas were similar to the values in peas from 2014. The starch characteristics of the yellow peas were most comparable to 2014 and 2015. The starch pasting values tended to be higher than peas from 2012 and 2013, but less than values reported in 2011.

Within each market class, variability in starch characteristics was observed among cultivars. In the green market class, the Viper cultivar had the highest peak, hot paste and cold paste viscosities (Table 16). In contrast, CDC Raezer, Daytona and Columbian had the lowest peak, hot paste and cold paste viscosities, respectively. The breakdown of starch during heating was greatest in Arcadia and least in Blue Moon. The highest and lowest peak, hot paste, and cold paste viscosities of the peas in the yellow market class were observed in Abarth and AAC Carver cultivars, respectively (Table 16). AAC Carver had the lowest viscosities among yellow cultivars. The breakdown of starch during heating was greatest in Nette and least in AAC Carver. 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 3-29 RVU, which represents little breakdown of the starch paste. This type of starch is ideal for glass noodle production.

Table 16. Mean starch characteristics of dry pea cultivars grown in the USA in 2016.

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**	152	134	18	267	133	4.93	73.4
	Arcadia	173	144	29	296	153	4.97	76.3
	Ariel	163	144	19	276	132	5.20	77.1
	Banner	137	120	17	222	101	5.24	76.5
	Blue Moon**	131	128	3	217	90	5.60	78.3
	CDC Raezer**	123	116	7	225	109	5.13	74.3
	CDC Striker	138	124	14	243	119	5.22	76.5
	Columbian**	129	115	13	182	67	5.33	79.9
	Daytona	125	106	19	219	113	5.23	72.5
	Ginny	141	122	19	255	133	4.91	75.1
	Greenwood	151	139	12	264	125	5.18	76.4
	Majoret	141	122	19	259	137	4.77	75.9
	Shamrock	148	140	8	244	104	5.33	77.4
	Viper	174	154	20	337	183	5.30	76.3
Yellow	AAC Carver**	110	108	3	193	85	5.47	76.7
	Abarth**	163	157	7	304	147	5.40	75.0
	AC Earlystar	137	132	5	249	116	5.43	75.8
	Admiral**	140	133	7	230	97	5.33	75.1
	Agassiz	135	124	11	236	112	5.21	75.4
	Bridger**	153	138	15	236	98	5.00	75.0
	Carousel**	162	142	20	267	125	5.13	75.8
	CDC Meadows	149	134	15	287	154	5.13	74.2
	Durwood**	137	126	11	193	68	5.27	76.0
	Jetset	126	117	9	205	88	5.61	75.3
	Leroy**	146	132	14	253	122	5.33	75.9
	Mystique	142	131	11	241	110	5.18	75.5
	Nette**	151	125	26	250	124	4.87	72.6
	Universal**	139	119	20	216	97	4.93	74.2
	Unknown	155	139	16	273	134	5.21	75.3

*Value for only one sample.

Lentil Quality Results

Sample distribution

A total of 50 lentil samples were collected from Idaho, Montana, North Dakota and Washington and delivered between September and December 2016. Growing location, number of samples, market class, and genotype details of these samples are provided in Table 17.

Table 17. Description of lentils used in the 2016 pulse quality survey.

State	No. of Samples	Market class	Cultivars
Montana	12	Green	Avondale
			CDC Imvincible CL
			CDC Richlea
			CDC Viceroy
		Red	CDC Maxim
			CDC Redcoat
		Spanish Brown	Pardina
North Dakota	29	Green	CDC Meteor
			CDC Richlea
			CDC Viceroy
			Merrit
		Red	CDC Maxim
Washington/ Idaho	9	Green	CDC Richlea
			Merrit
		Spanish Brown	Pardina

Proximate composition of lentils (Tables 18-20)

Moisture

The moisture content of lentils ranged from 6.9 to 11.1% in 2016 (Table 18). The mean moisture content of the 9.0% was higher than the 5-year mean of 8.2%, but lower than lentils from 2014 and 2015. Lentils grown in 2016 had a moisture content comparable to lentils from 2012. Overall, all samples evaluated had moisture contents below the 13-14% recommended for general storability.

The moisture contents of the red and green market classes were approximately the same (Table 19). The red and green seeds had moisture contents of 9.3 and 9.2%, respectively and were higher than the 7.8% moisture content observed in the Spanish brown lentils and the 5-year (2011-2014) mean value. The highest moisture contents were observed in the CDC Meteor, and CDC Richlea cultivars (i.e., green lentils) and CDC Maxim 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 2.1-3.0% with a mean of 2.5% (Table 18). The mean ash content of lentils grown in 2016 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 were essentially the same (Table 19). The ash contents of the different market classes were lower than other crop years. CDC Imvincible cultivar had the highest ash content among cultivars (Table 20).

Protein

Protein content of lentils ranged from 17.9-24.6%, with a mean of 21.7% (Table 18). The mean protein content of lentils grown in 2016 was similar to the 2011 harvest year (i.e. 22%), but lower than the 5-year mean of 23.4%. This difference likely would not affect handling and processing of the lentils. Although, protein isolation might be affected slightly.

The protein contents of the three market classes were different (Table 19). Red lentils had the highest mean protein content (23.3%) among lentil market classes while green and Spanish brown lentils had values around 21.4% and 20.1%, respectively. The CDC Viceroy (green) and CDC Maxim (red) cultivars had the highest protein among known cultivars (Table 20).

Table 18. Proximate composition of lentils grown in the USA, 2011-2016.

Proximate Composition (%)	2016 Range	2016 Mean (SD)	2015 Mean	2014 Mean	2013 Mean	2012 Mean	2011 Mean	5-year Mean (SD)
Moisture	6.9-11.1	9.0 (1.0)	10	11	5	8	7	8.2 (2.4)
Ash	2.1-3.0	2.5 (0.2)	2.7	2.5	2.4	2.8	2.7	2.6 (0.2)
Protein	17.9-24.6	21.7 (1.6)	23	24	23	25	22	23.4 (1.1)
Total Starch	36.4-51.3	43.3 (3.1)	38	44	54	52	40	45.6 (7.1)

Table 19. Proximate composition of different market classes of lentils grown in the USA, 2011-2016.

Market Class	Proximate Composition (%)	Mean (SD) 2016	2015	2014	2013	2012	2011	5-Year Mean (SD)
Green	Moisture	9.2 (0.9)	9.8 (1)	10.9 (1.2)	5 (1)	9 (1)	7 (1)	8 (2)
	Ash	2.5 (0.2)	2.9 (0.2)	2.4 (0.1)	2.3 (0.2)	2.7 (0.2)	2.7 (0.2)	2.6 (0.2)
	Protein	21.4 (1.5)	22.5 (1)	23.2 (1.5)	23 (3)	25 (2)	22 (2)	23 (1)
	Total Starch	43.3 (3.2)	38.5 (2)	44.6 (3.5)	55 (6)	52 (3)	40 (5)	46 (7)
Red	Moisture	9.3 (0.8)	10.4 (1)	10.0 (0.8)	5 (3)	8 (0.3)	7 (1)	8 (2)
	Ash	2.6 (0.2)	2.7 (0.4)	2.9 (0.6)	2.6 (0.4)	3.0 (0.2)	2.5 (0.3)	2.7 (0.2)
	Protein	23.3 (1.2)	22.8 (2)	24.2 (1.3)	25 (2)	25 (2)	22 (2)	24 (1)
	Total Starch	44.9 (1.8)	39.1 (2)	41.2 (0.6)	52 (5)	53 (4)	41 (5)	45 (7)
Spanish Brown	Moisture	7.8 (0.7)	8.9 (1)	9.7	*	*	*	nd
	Ash	2.5 (0.3)	2.9 (0.2)	2.2	*	*	*	nd
	Protein	20.7 (1.0)	22.8 (1)	22.2	*	*	*	nd
	Total Starch	41.1 (2.8)	36.8 (4)	42.5	*	*	*	nd

*= not reported; nd = not determined

Total starch

Total starch content of lentils ranged from 36.4 to 51.3%, with a mean of 43.3% (Table 18). The mean total starch content of lentils grown in 2016 was similar to the 2014 harvest year (i.e. 44%), but lower than the 5-year mean of 45.6%, primarily due to the higher starch composition observed in 2012 and 2013 (52-54%).

The starch content of the red market class was 1.6 and 3.8 percentage points higher than the mean starch contents of the green and Spanish brown lentils (Table 19). Red lentils had a mean starch content (44.9%) that was higher than red lentils from 2011, 2014 and 2015 harvest years. The green lentils had a mean starch content (44.9%) that was higher than green lentils from 2011, and 2015 harvest years. The Spanish brown lentils had total starch contents that were higher than lentils from 2015, but lower than the 2014 harvest year. The highest starch content was observed in CDC Redcoat followed by CDC Meteor (Table 20). The Merrit cultivar had the lowest (39.1%) starch content among known cultivars tested (Table 20).

Table 20. Mean proximate composition of lentil cultivars grown in the USA in 2016.

Market Class	Cultivar	Concentration (%) Moisture	Ash	Protein	Starch
Green	Avondale**	8.8	2.5	22.5	45.6
	CDC Imvincible CL**	8.0	2.7	21.9	45.1
	CDC Meteor	9.5	2.5	23.3	46.7
	CDC Richlea	9.5	2.5	21.0	43.3
	CDC Viceroy	8.1	2.4	24.0	44.9
	Merrit	7.3	2.6	21.8	39.1
Red	CDC Maxim	9.4	2.6	23.7	44.2
	CDC Redcoat**	9.0	2.6	20.6	48.5
Spanish Brown	Pardina	7.8	2.5	20.7	41.1

**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 content of lentil classes from 2016 was lower than the previous 5 years (2011-2015). The lentils from 2016 had mean potassium levels of 4997 mg/kg in Spanish brown to 5637 mg/kg in the red market class. Phosphorus content in Spanish brown lentils was approximately 800 to 1,200 mg/kg higher than the red and green lentils in 2016. The phosphorus contents of lentils in the green lentil class was higher in 2016 samples than lentils from other harvest years (Table 21). Similar trends were observed in the red and Spanish brown market classes. Calcium in green lentils from 2016 tended to be higher than calcium contents of green lentils grown in previous years except 2014. Red lentils from 2016 had calcium contents higher than 2011-2013 harvest years, similar calcium contents to lentils from the 2015, but lower values compared to the 2014 harvest year. Magnesium composition in lentils from 2016 tended to be lower than values in the lentils from 2015, regardless of market class, but higher than lentils from other harvest years. The trace mineral (copper, manganese) content in lentils had values that were similar to the previous 5 years. The iron contents of lentils harvested in 2016 were lower than those values reported in 2015, but were comparable to lentils from previous years (2011-2014) (Table 21). Mean zinc and selenium (other trace minerals) contents of lentils, regardless of market class, grown in 2016 were significantly lower than the mean zinc and selenium contents from 2011-2015.

Table 21. Mineral concentrations of lentils grown in the USA, 2011-2016.

Market Class	Mineral	2016 mean (std dev.)	2015 mean (std dev.)	2014 mean (std dev.)	2013 mean (std dev.)	2012 mean (std dev.)	2011 mean (std dev.)	5-year Mean
Green	Calcium	534 (67)	449 (54)	761 (89)	496 (81)	293 (79)	501 (62)	500
	Copper	6 (1)	7 (1)	7 (1)	7 (2)	*	*	7**
	Iron	62 (14)	80 (38)	61 (9)	57 (18)	69 (39)	53 (6)	67
	Magnesium	1026 (67)	1149 (75)	789 (27)	597 (185)	367 (109)	761 (40)	733
	Manganese	12 (3)	13 (2)	17 (4)	15 (4)	*	*	15**
	Potassium	5401 (506)	6111 (791)	8493 (295)	6936 (1463)	6954 (709)	6255 (447)	6950
	Phosphorus	3890 (744)	2625 (359)	2574 (156)	2931 (829)	*	*	2710**
	Zinc	25 (4)	27 (4)	40 (4)	35 (10)	34 (8)	29 (4)	33
	Selenium (µg/kg)	179 (33)	279 (32)	369 (37)	727 (382)	726 (403)	698 (273)	560
Red	Calcium	573 (92)	590 (177)	647 (38)	460 (56)	418 (85)	569 (99)	537
	Copper	7 (1)	7 (1)	7 (1)	7 (3)	*	*	7**
	Iron	64 (12)	123 (90)	62 (5)	75 (28)	79 (18)	67 (6)	85
	Magnesium	1035 (87)	1145 (90)	772 (23)	677 (175)	482 (83)	720 (47)	759
	Manganese	15 (3)	15 (2)	13 (1)	20 (5)	*	*	16**
	Potassium	5637 (939)	5962 (575)	8416 (730)	7761 (2607)	7243 (896)	6108 (463)	7098
	Phosphorus	3569 (625)	2695 (162)	2960 (177)	3909 (1491)	*	*	3188**
	Zinc	27 (7)	29 (6)	41 (6)	45 (16)	40 (4)	33 (6)	38
	Selenium (µg/kg)	189 (28)	269 (32)	397 (30)	379 (143)	503 (174)	495 (158)	409
Spanish Brown	Calcium	479 (64)	457 (34)	*	*	*	*	*
	Copper	6 (1)	8 (1)	*	*	*	*	*
	Iron	62 (21)	109 (43)	*	*	*	*	*
	Magnesium	934 (38)	1168 (75)	*	*	*	*	*
	Manganese	10 (2)	14 (2)	*	*	*	*	*
	Potassium	4997 (303)	6609 (791)	*	*	*	*	*
	Phosphorus	4722 (437)	3137 (289)	*	*	*	*	*
	Zinc	28 (4)	33 (5)	*	*	*	*	*
	Selenium (µg/kg)	166 (32)	239 (47)	*	*	*	*	*

*data not reported / determined; **3-year mean

Table 22. Mean mineral concentrations of lentil cultivars grown in the USA in 2016.

Market Class	Cultivar	Concentration (mg/kg)* Ca	Cu	Fe	K	Mg	Mn	P	Zn	(µg/kg) Se
Green	Avondale**	550	6	52	5108	1032	9	3952	24	151
	CDC Imvincible CL**	539	6	53	4695	914	8	3386	26	185
	CDC Meteor	522	6	59	6342	1143	14	3158	27	194
	CDC Richlea	539	6	62	5391	1027	11	3912	24	183
	CDC Viceroy	481	6	54	5277	993	12	3497	27	170
	Merrit	527	7	75	5278	999	14	4608	27	146
Red	CDC Maxim	599	7	65	5825	1049	15	3388	28	191
	CDC Redcoat**	417	6	58	5142	983	17	4275	26	190
Spanish Brown	Pardina	479	6	62	4997	934	10	4722	28	166

*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 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, CDC Maxim had a calcium content of 599 mg /kg while CDC Redcoat contained 417 mg/kg. The CDC Imvincible cultivar had a magnesium content of 914 mg/kg while 1143 mg/kg was observed in the Meteor cultivar. These same cultivars had the lowest and highest potassium contents, respectively (Table 22). The Meteor cultivar had a phosphorus content of 3158 mg/kg while 4722 mg/kg was observed in the Pardina cultivar. Variability existed in the trace minerals, but to a lesser degree (Table 22). Iron content ranged from 52 in Avondale to 75 mg/kg in Merrit while selenium ranged from 146 µg/kg in the Merrit cultivar to 194 µg/kg in the CDC Meteor cultivar. Regardless of the specific mineral, the composition of minerals in lentils was high.

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 2016 and comparisons to the 5-year mean value.

Test weight ranged from 54-67 lbs/ bu with a mean of 62 lbs/bu. This mean value was slightly higher than the 5-year mean of 61 lbs/bu (Table 23). The test weight for all lentil samples harvested in 2016 was comparable to lentils harvested in previous years. The mean test weight of lentils in the Spanish brown market class was 2 to 3 percentage points higher than test weights of lentils from the red and green market classes. Although overall test weights differed among market classes, maximum tests weights of individual cultivars crossed all market classes. CDC Viceroy (green), CDC Redcoat (red) and Pardina (Spanish brown) all had test weights of 66 lbs/bu (Table 25).

The range and mean **1000 seed weight** of lentils grown in 2016 were 28-69 g and 45 g, respectively (Table 23). The mean value was the same as the 5-year mean of 45 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, 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 49 g, which was significantly higher than the previous 5 years (Table 24). The Spanish brown had a mean 1000 seed weight that was the same as lentils from 2014, but 2 percentage points lower than 2015. The individual cultivars varied extensively in 1000 seed weight. CDC Imvincible had the lowest 1000 seed weight at 28 g, followed by CDC Viceroy. Merrit had the highest 1000 seed weight at 61 g.

Water hydration capacity of lentils ranged from 54 to 111%, with a mean of 91% (Table 23). The 2016 mean value was similar to lentils from previous years except 2015, which had higher water hydration capacities. The 5-year mean water hydration capacities of 97% was higher than the mean water hydration in lentils from 2016. The water hydration capacity (95%) was highest for green lentils followed by the red (87%) and Spanish brown (79%) market classes (Table 24). The water hydration capacities of the green and Spanish brown were substantially lower than lentils from their respective market classes in 2015 (Table 24). However, in the green market class the mean water hydration was higher than those observed in 2011-2013. The red and Spanish brown market classes had mean water hydration capacities that were lower than lentils from previous crop years. The water hydration capacity ranged from 75% in CDC Viceroy (green) to 102% in Merrit (green). Most other cultivars ranged from 83 to 96% (Table 25).

Unhydrated seed percentage ranged from 0-38% with a mean of 4%, which was less than the 5-year mean of 5% (Table 23). The unhydrated seed were higher in 2016 lentils compared to 2014 and 2015 harvest years, but less than lentils from the 2011-2013 harvest years. The amount of unhydrated seeds in all market classes were not different (Table 24). With the exception of the red lentils in 2012 and 2013, fewer unhydrated seed existed in red lentils from other harvest years compared to 2016. The green lentils from 2016 had comparable unhydrated seeds amounts to the previous five years except 2011 and 2013, which had higher unhydrated seed amounts (Table 24). The unhydrated seed count was significantly higher in the Spanish brown lentils from 2016 compared to 2015. The CDC Meteor and Merrit cultivars had the lowest number of unhydrated seeds at 1% while CDC Viceroy and Pardina had the highest at 12-13% (Table 25).

The **swelling capacity** of all lentils ranged from 84-236%, with a mean value of 140% (Table 23). The swelling capacity from 2016 samples was greater than that of lentils from the 2014 harvest, but lower than swell-

Table 23. Physical parameters of lentils grown in the USA, 2011-2016.

Physical Parameters	2016 Range	2016 Mean (SD)	2015 Mean	2014 Mean	2013 Mean	2012 Mean	2011 Mean	5-year Mean (SD)
Test Weight (lb/Bu)	54-67	62 (3)	63	61	62	61	60	61 (1)
1000 Seed Wt (g)	28-69	45 (9)	43	44	46	45	49	45 (2)
Water Hydration Capacity (%)	54-111	91 (11)	118	94	90	94	88	97 (12)
Unhydrated Seeds (%)	0-38	4 (7)	1	2	7	7	6	5 (3)
Swelling Capacity (%)	84-236	140 (28)	161	102	*	*	*	nd
Cooked Firmness (N/g)	9.3-24.8	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, 2011-2016.

Market class	Physical Parameter	2016	2015	2014	2013	2012	2011	5-Year Mean
Green	Test Weight (lb/Bu)	62 (2)	62 (2)	63 (3)	63 (2)	61 (1)	61 (2)	62 (1)
	1000 Seed Wt (g)	49 (8)	47 (9)	32 (5)	45 (6)	39 (11)	42 (11)	41 (6)
	Water Hydration Capacity (%)	95 (9)	121 (18)	94 (4)	82 (22)	85 (51)	86 (20)	94 (16)
	Unhydrated Seeds (%)	2 (4)	1 (1)	3.0 (1)	11 (7)	2 (3)	9 (8)	5 (4)
	Swelling Capacity (%)	148 (26)	148 (32)	103 (9)	*	*	*	nd
	Cooked Firmness (N/g)	13.5 (2.8)	12.5 (2.0)	*	*	*	*	nd
Red	Test Weight (lb/Bu)	63 (4)	64 (1)	60 (3)	62 (1)	60 (2)	59 (2)	62 (2)
	1000 Seed Wt (g)	36 (3)	36 (2)	50 (9)	49 (7)	47 (11)	56 (9)	42 (5)
	Water Hydration Capacity (%)	87 (3)	98 (9)	95 (2)	89 (21)	98 (17)	91 (14)	89 (7)
	Unhydrated Seeds (%)	4 (3)	2 (1)	2.0 (1)	6 (8)	6 (7)	3 (4)	5 (4)
	Swelling Capacity (%)	125 (21)	155 (15)	105 (10)	*	*	*	nd
	Cooked Firmness (N/g)	13.2 (2.1)	12.0 (1.0)	*	*	*	*	nd
Spanish Brown	Test Weight (lb/Bu)	66 (1)	64 (2)	66	*	*	*	nd
	1000 Seed Wt (g)	36 (2)	38 (8)	36	*	*	*	nd
	Water Hydration Capacity (%)	79 (16)	124 (6)	91	*	*	*	nd
	Unhydrated Seeds (%)	13 (13)	1 (1)	2	*	*	*	nd
	Swelling Capacity (%)	118 (26)	191 (23)	115	*	*	*	nd
	Cooked Firmness (N/g)	13.1 (0.8)	10.8 (1.3)	*	*	*	*	nd

*= not reported; nd = not determined

ing capacities of lentils from the 2015 harvest year. The swelling capacity of lentils was similar between red and Spanish brown market classes (Table 24). Swelling capacities of 148% was observed in the green market class for lentils grown in 2016, which was identical to swelling capacities in the 2015 lentils. CDC Imvincible had the greatest swelling capacity (186%) followed by Merrit (Table 25). CDC Viceroy had the lowest swelling capacity among the cultivars tested (Table 25). The amount of unhydrated seeds was also greatest in CDC Viceroy and thus the low swelling capacity was not unexpected. The CDC Viceroy cultivar also had low swelling capacity in 2015.

The **cooked firmness** of all lentils ranged from 9.3 to 24.8 N/g with a mean value of 13.4 N/g (Table 23). The lentils from 2016 had slightly greater cooked firmness values than lentils from 2015. 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 2016 lentils from their respective market classes were more firm than lentils from 2015. Among the cultivars, CDC Redcoat had the lowest cooking firmness while CDC Meteor 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 2016 this trend was not observed.

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 2016 indicated that the lentils had slightly lower L* values than the previous crop years (2011-2015). This data indicates that the lentils from the 2016 crop year were darker in color than those from previous years. The lower "a" value (i.e., red-green scale) in the red lentil indicates a less red color while a more negative "a" value for the green lentils indicates a greener color. In 2016, the "a" value of 7.97 was higher than values from other years. This indicates that the lentils from 2016 were slightly more red than the lentils from previous harvest years. In the green lentil market class, the 2016 samples were less green based on the higher "a" values compared to previous years (Table 26). The Spanish brown "a" value was slightly higher than 2014 indicating more greenness in the sample.

The "b" value for red lentils from 2016 indicated a less yellow color compared to the previous crops years. The "b" value for green lentils from 2016 indicated a yellower color compared to the previous years except 2011 and 2013 crop years.

The color of the lentils changed after the soaking process. All market classes became lighter as evidenced by the higher L* values (Table 26) compared to pre-soaked lentils. This same trend occurred in 2013 for the red and green market classes. The green lentil lightness value increased after soaking, which also occurred in the 2015 green lentils. In the red lentil market class, a trend to increasing redness was observed in lentil from 2011-2015 after soaking, this same trend occurred in 2016. The Spanish brown redness value also increased upon soaking of the lentil. In contrast, the "a" value decreased, supporting a greener color for the lentils in the green market class. Lentils from all market classes became more yellow (i.e., increased b value) after soaking. The color change in lentil samples was similar for the red and Spanish brown market classes (Table 26). These values were similar to the values observed in 2014, but higher than those from the 2015 harvest year. The green market class had lower

Table 25. Mean physical parameters of USA lentil cultivars grown in 2016.

Market Class	Cultivar	Test Weight (lb/bu)	1000 Seed Wt (g)	Water Hydration Capacity (%)	Unhydrated Seeds (%)	Swelling Capacity (%)	Cooked Firmness (N/g)
Green	Avondale**	65	45	93	3	146	11.9
	CDC Imvincible CL**	59	28	88	6	186	12.3
	CDC Meteor	62	53	89	1	127	18.8
	CDC Richlea	62	49	96	2	151	12.2
	CDC Viceroy	66	31	75	12	97	14.6
	Merrit	61	61	102	1	157	12.3
Red	CDC Maxim	62	36	88	4	121	13.9
	CDC Redcoat**	66	39	82	9	140	9.8
Spanish Brown	Pardina	66	36	79	13	118	13.2

**Only one sample of cultivar tested

color differences compared to the red and Spanish brown market categories, indicating greater color stability among green lentils.

Among the cultivars, Pardina had the lowest L* value followed by CDC Redcoat (Table 27). The highest L* was CDC Meteor. 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). 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 in all lentils during soaking. The green lentil cultivar Avondale had the highest "b" value (i.e. yellowness) of the soaked lentils. This is a green coated lentil but has a yellow cotyledon; thus, the soaking may have reduced the impact of the hull on color and resulted in increased yellowness. The greatest color difference was observed in the CDC Redcoat cultivar (Table 27). The increase in redness and yellowness during soaking likely contributed to the greatest color difference in this cultivar. CDC Viceroy was the most stable as this cultivar had the lowest color difference value.

Starch properties

(Tables 28-30)

Peak viscosity, hot and cold paste viscosities and setback values of lentils grown in 2016 were higher than lentils from 2009-2015, except for lentils harvested in 2011 (Table 28). Mean peak time was significantly less than the 5-year mean value, but was similar to 2014 and 2015; indicating a more rapid viscosity increase for the lentils harvest in 2016. Pasting temperature ranged from 74 to 78°C, with a mean value of 76 °C. The starch characteristics were similar among the different lentil market classes (Table 29). For example, cold paste viscosities of 238, 237 and 247 RVU

Table 26. Color quality of lentils grown in the USA before and after soaking, 2011-2016.

	Mean (SD) of red lentils											
	Before soaking						After soaking					
Color scale*	2016	2015	2014	2013	2012	2011	2016	2015	2014	2013	2012	2011
L (lightness)	45.95 (1.70)	56.84 (5.35)	56.06 (0.54)	54 (8)	55 (2)	54 (1)	49.54 (0.75)	52.51 (0.60)	51.82 (0.16)	57 (8)	52 (3)	52 (2)
a (red-green)	7.97 (0.63	3.71 (1.63)	4.19 (0.69)	5.4 (1)	3.9 (1)	4.3 (1)	13.84 (1.08)	8.64 (0.22)	7.83 (0.32)	10 (2)	7.7 (1)	7.3 (2)
b (blue-yellow)	14.34 (1.34)	18.58 (4.60)	7.57 (1.20)	15 (4)	9 (2)	8 (2)	27.04 (1.85)	20.29 (1.45)	21.98 (0.58)	28 (7)	19 (1)	18 (1)
Color Difference	14.51 (2.04)	6.37 (2.22)	15.46	**	**	**						

	Mean (SD) of green lentils											
	Before soaking						After soaking					
Color scale*	2016	2015	2014	2013	2012	2011	2016	2015	2014	2013	2012	2011
L (lightness)	55.22 (1.19)	57.14 (5.76)	63.12 (0.93)	60 (2)	60 (1)	60 (1)	58.23 (2.01)	62.29 (1.18)	59.91 (2.28)	67 (7)	59 (2)	60 (1)
a (red-green)	4.69 (1.42)	2.49 (2.17)	2.25 (1.56)	1 (2)	1.1 (1)	2.1 (0.4)	4.06 (1.42)	0.59 (1.79)	0.59 (2.19)	-0.2 (2)	-0.4 (1)	1 (0.6)
b (yellow-blue)	23.16 (1.38)	19.55 (5.02)	15.36 (0.22)	23 (1)	15 (1)	24 (1)	32.30 (2.60)	28.30 (1.62)	25.79 (2.15)	35 (6)	23 (2)	24 (1)
Color Difference	9.82 (1.96)	6.18 (1.62)	11.10	**	**	**						

	Mean (SD) of brown lentils											
	Before soaking						After soaking					
Color scale*	2016	2015	2014	2013	2012	2011	2016	2015	2014	2013	2012	2011
L (lightness)	42.92 (1.12)	55.71 (5.26)	54.5	**	**	**	47.88 (1.69)	51.21 (2.82)	54.3	**	**	**
a (red-green)	5.21 (0.20)	3.43 (2.79)	2.2	**	**	**	6.59 (0.45)	4.66 (0.69)	0.99	**	**	**
b (yellow-blue)	12.07 (0.94)	17.95 (4.79)	6.65	**	**	**	26.59 (1.31)	19.54 (1.84)	23.91	**	**	**
Color Difference	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

were recorded for the red, green and Spanish brown market classes, respectively (Table 29). The starch characteristics of the lentils from their respective market classes were greater than those from all harvest years except 2011.

Variability in starch characteristics were observed among cultivars (Table 30). The red lentil cultivars had nearly identical starch characteristics except for peak and hot paste viscosities. The CDC Redcoat cultivar had lower peak and hot paste viscosities than the CDC Maxim. In the green market class, the variability among cultivars was noticeable. CDC Viceroy had the lowest peak (124 RVU), hot paste (117 RVU), and cold paste (211 RVU) viscosities among the green lentil cultivars. In contrast, CDC Richlea had the highest viscosity values (Table 30).

Table 27. Color quality of USA lentil cultivars before and after soaking, 2016.

		Mean Color Values*						
		Before Soaking			After Soaking			
Market Class	Cultivar	L	a	b	L	a	b	Color Difference
Green	Avondale**	56.11	2.26	24.72	60.30	2.17	36.75	12.74
	CDC Imvincible CL**	55.04	3.35	23.29	58.36	2.00	32.85	10.26
	CDC Meteor	57.13	4.35	23.91	60.17	3.56	32.38	9.07
	CDC Richlea	55.37	4.54	23.43	58.46	4.08	32.91	10.10
	CDC Viceroy	54.85	3.57	23.05	58.69	1.85	27.38	6.24
	Merrit	52.72	8.18	19.90	54.01	7.04	28.77	9.21
Red	CDC Maxim	46.26	7.99	14.48	49.58	13.73	26.68	13.96
	CDC Redcoat**	44.66	7.95	13.65	49.04	14.73	29.86	18.11
Spanish Brown	Pardina	42.92	5.21	12.07	47.88	6.59	26.59	15.56

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

Table 28. Starch characteristics of lentils grown in the USA, 2010-2016.

	2016		2015	2014	2012	2011	2010	5-year
Starch Characteristic	Range	Mean (SD)	Mean	Mean	Mean	Mean	Mean	Mean (SD)
Peak Viscosity (RVU)	7672-191	148 (20)	124	121	119	185	124	135 (28)
Hot Paste Viscosity (RVU)	48-159	133 (18)	119	115	112	145	112	121 (14)
Breakdown (RVU)	4-33	15 (6)	4	6	7	41	12	14 (15)
Cold Paste Viscosity (RVU)	87-282	239 (31)	205	196	208	323	205	227 (54)
Setback (RVU)	39-138	106 (16)	86	81	96	178	93	107 (40)
Peak Time (Minute)	4.53-5.67	5.16 (0.26)	6	6	9.9	8.1	8.9	7.78 (1.75)
Pasting Temperature (°C)	74.2-77.6	75.9 (1.0)	77	76	*	*	*	nd

*data not reported in 2013; nd = not determined

Table 24. Physical parameters of different market classes of lentils grown in the USA, 2011-2016.

Market class	Physical Parameter	Mean (SD) 2016	2015	2014	2013	2012	2011	4-Year Mean (SD)
Green	Peak Viscosity (RVU)	149 (22)	127 (17)	131 (12)	*	121 (14)	191 (19)	143 (33)
	Hot Paste Viscosity (RVU)	132 (20)	121 (14)	122 (9)	*	114 (11)	147 (13)	126 (14)
	Breakdown (RVU)	17 (6)	6 (5)	9 (5)	*	7 (7)	44 (7)	17 (18)
	Cold Paste Viscosity (RVU)	237 (35)	208 (25)	205 (25)	*	212 (3)	326 (45)	238 (59)
	Setback (RVU)	105 (18)	87 (14)	83 (17)	*	98 (15)	44 (7)	78 (24)
	Peak Time (Minute)	5.10 (0.20)	6 (1)	5 (0)	*	10 (1)	8 (0)	7 (2)
	Pasting Temperature (°C)	76.0 (1.0)	77 (4)	76 (1)	*	*	*	nd
Red	Peak Viscosity (RVU)	141 (13)	112 (23)	106 (9)	*	99 (13)	174 (27)	123 (35
	Hot Paste Viscosity (RVU)	132 (14)	108 (20)	104 (9)	*	96 (13)	138 (16)	112 (18)
	Breakdown (RVU)	9 (3)	4 (3)	2 (1)	*	4 (5)	36 914)	12 (16)
	Cold Paste Viscosity (RVU)	238 (18)	190 (33)	181 (14)	*	180 (30)	310 (49)	215 (63)
	Setback (RVU)	106 (12)	82 (15)	77 (6)	*	84 (20)	171 (34)	104 (45)
	Peak Time (Minute)	5.47 (0.24)	6 (1)	6 (1)	*	11 (2)	8 (0)	8 (2)
	Pasting Temperature (°C)	75.9 (1.2)	76 (1)	77 (1)	*	*	*	nd
Spanish Brown	Peak Viscosity (RVU)	148 (14)	123 (10)	131 (12)	*	*	*	nd
	Hot Paste Viscosity (RVU)	135 (17)	121 (10)	122 (9)	*	*	*	nd
	Breakdown (RVU)	14 (4)	2 (1)	9 (5)	*	*	*	nd
	Cold Paste Viscosity (RVU)	247 (26)	210 (20)	205 (25)	*	*	*	nd
	Setback (RVU)	113 (12)	89 (11)	83 (17)	*	*	*	nd
	Peak Time (Minute)	5.13 (0.26)	6 (1)	5 (0)	*	*	*	nd
	Pasting Temperature (°C)	75.7 (0.8)	79 (1)	76 (1)	*	*	*	nd

*data not reported; nd = not determined

Table 30. Mean starch characteristics of lentil cultivars grown in the USA in 2016.

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**	149	132	17	232	99	5.20	74.4
	CDC Imvincible CL**	146	127	19	225	99	4.73	76.0
	CDC Meteor	154	140	14	233	93	5.27	75.5
	CDC Richlea	152	134	18	241	107	5.07	76.2
	CDC Viceroy	124	117	6	211	93	5.27	74.6
	Merrit	141	127	14	235	108	5.00	75.9
Red	CDC Maxim	142	134	8	236	103	5.51	75.9
	CDC Redcoat**	123	112	11	236	124	5.00	74.3
Spanish Brown	Pardina	148	135	14	247	113	5.13	75.7

* Value from only one sample.

Chickpea Quality Results

Sample distribution

A total of 18 chickpea samples were collected from Idaho, Montana, North Dakota and Washington between July and October 2016. Samples were delivered to NDSU between September and December 2016. Growing location, number of samples, market class, and genotype details of these samples are provided in Table 31.

Table 31. Description of chickpea samples used in the 2016 pulse quality survey.

State	No of samples	Market class	Cultivars
Montana	1	Kabuli	Not Given
North Dakota	5	Kabuli	CDC Alma CDC Frontier CDC Orion
Washington/Idaho	12	Kabuli	Billy Beans Bronic Sierra Troy

Proximate composition of chickpea (Tables 32-33)

The **moisture content** of chickpeas ranged from 6.2-12.3% in 2016 (Table 32). The mean moisture content of the samples was 8.7%, which is higher than the 5-year mean of 8%. Chickpeas grown in 2016 had a mean moisture content that was the same as chickpeas grown in 2015 and lower than the 2014 mean moisture content of 11%. CDC Alma had the highest moisture content at 12.3% while the Bronic cultivar had the lowest moisture (7.2%). The moisture contents of all samples were below the 13% recommended for general storability. **Ash content** of chickpeas ranged from 2.5-3.0% with a mean of 2.7% (Table 32). The mean ash content of chickpeas grown in 2016 was comparable to other previous harvest years. CDC Alma had the lowest ash content at 2.5% while Troy had the highest (2.9%).

Protein content of chickpeas ranged from 16.5-21.2%, with a mean of 18.3% (Table 32). The mean protein content of chickpeas grown in 2016 was lower than the 5-year mean of 21%, but was similar to the 2015 crop. The 2015 and 2016 crops included more diverse set of samples compared to any of the previous years and thus more accurately reflects the available chickpeas. CDC Alma had a protein content of 16.5% while Bronic had a protein content of 20.7% (Table 33). Growing conditions may have impacted protein content.

Total starch content of chickpeas ranged from 34.0 to 49.3% with a mean of 40.0% (Table 32). The mean total starch content of chickpeas grown in 2016 was similar (i.e. 40%) to the 2011, 2014 and 2015 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 CDC Frontier cultivar from 2014 and 2015 had mean starch contents of 42.3 and 42.7%, respectively. This same cultivar in 2016 had a mean starch content of 42.6% (Table 33), which demonstrated a consistent starch content among the three years. The Billy Bean cultivar had the lowest starch content of 35.6% while the highest starch content was 43.6% in the CDC Orion cultivar.

Table 32. Proximate composition of chickpeas grown in the USA, 2011-2016.

Proximate Composition**	2016 Range	2016 Mean (SD)	2015 Mean (SD)	2014* Mean (SD)	2013 Mean (SD)	2012 Mean (SD)	2011 Mean (SD)	5-year Mean (SD)
Moisture (%)	6.2-12.3	8.7 (1.7)	9 (1)	11 (1)	3 (2)	8 (1)	7 (1)	8 (3)
Ash (%)	2.5-3.0	2.7 (0.1)	2.7 (0.1)	2.5 (0.2)	2.8 (0.2)	2.9 (0.2)	2.8 (0.1)	2.8 (0.2)
Protein (%)	16.5-21.2	18.3 (1.4)	19 (1)	20 (2)	21 (2)	21 (2)	21 (2)	21 (1)
Starch (%)	34.0-49.3	40.0 (4.2)	41 (5)	42 (1)	53 (6)	50 (5)	41 (7)	45 (6)

*2014 data is for Frontier cultivar only; **composition is on an “as is” basis

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 5928 mg/kg in 2016, this values is less than the 5-year mean. Phosphorus content in chickpea from 2016 was well below the phosphorus content of chickpeas from 2013 but higher than the phosphorus contents of chickpeas from 2014 and 2015. Calcium was higher in chickpea grown in 2016 compared to the previous years except 2014. Magnesium composition was higher in the chickpea samples from 2016 compared to chickpeas from previous years (Table 34). The trace minerals (copper, iron, manganese and zinc) of chickpeas harvested in 2016 tended to be lower than values of the previous 5 harvest years (Table

Table 33. Mean proximate composition of chickpea cultivars grown in the USA, 2016.

	Concentration (%)			
Cultivar	**Moisture**	**Ash**	**Protein**	**Starch**
Billy Bean	8.3	2.8	19.3	35.6
Bronic*	7.2	2.8	20.7	38.3
CDC Alma*	12.3	2.5	16.5	41.9
CDC Frontier	10.5	2.6	17.9	42.6
CDC Orion	9.9	2.7	16.6	43.6
Sierra	7.3	2.8	17.8	42.4
Troy*	7.3	2.9	19.3	39.8
Unknown*	10.3	2.6	18.6	38.0

* Value from only one sample.

Table 34. Mineral concentrations of chickpeas grown in the USA, 2011-2016.

	Year						
Micronutrient (mg/kg)	**2016 Mean (SD)**	**2015 Mean (SD)**	**2014* Mean (SD)**	**2013 Mean (SD)**	**2012 Mean (SD)**	**2011 Mean (SD)**	**5-year Mean**
Calcium	667 (154)	552 (114)	695 (75)	499 (238)	503 (158)	645 (82)	579
Copper	6 (1)	7 (1)	6 (1)	8 (2)	**	**	7#
Iron	41 (4)	48 (3)	46 (5)	51 (11)	43 (7)	43 (7)	46
Magnesium	1226 (114)	1188 (48)	900 (8)	1148 (88)	693 (97)	906 (72)	967
Manganese	35 (6)	29 (4)	33 (5)	44 (8)	**	**	35#
Potassium	5928 (642)	7558 (362)	10,077 (372)	9670 (1340)	7627 (1382)	6611 (406)	8309
Phosphorus	2882 (304)	2672 (189)	2642 (173)	3992 (1050)	**	**	3102#
Zinc	21 (2)	28 (7)	35 (4)	38 (9)	30 (7)	24 (6)	31
Selenium (µg/kg)	173 (40)	227 (43)	376 (30)	520 (264)	599 (504)	361 (2)	417

*2014 data is for Frontier cultivar only; **data not reported; #3-year mean value

Table 35. Mean mineral concentrations of chickpea cultivars grown in the USA, 2016.

	Year								µg/kg
Cultivar	**Ca**	**Cu**	**Fe**	**K**	**Mg**	**Mn**	**P**	**Zn**	**Se**
Billy Bean	786	6	43	5387	1144	35	2711	19	154
Bronic**	431	6	42	5901	1171	25	3083	25	147
CDC Alma**	659	8	42	6914	1444	35	3611	20	207
CDC Frontier	613	6	45	6912	1408	44	3367	24	203
CDC Orion	727	7	39	6220	1276	30	2934	20	191
Sierra	580	6	39	5645	1183	39	2705	21	150
Troy**	586	4	35	5646	1137	37	2627	20	147
Unknown**	814	7	42	6816	1318	26	2876	20	308

*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.

34). Mean selenium (another trace mineral) content of chickpeas grown in 2016 was significantly lower than the mean selenium contents of chickpeas from the prior five years. 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.

Copper, iron, manganese and zinc were comparable among cultivars tested (Table 35). The Billy Bean cultivar contained the highest (786 mg/kg) content of calcium while the Bronic cultivar contained the lowest (431 mg/kg). The CDC Alma contained the highest content of magnesium, potassium and phosphorus. Troy, Billy Beans and Sierra had the lowest contents of magnesium, potassium and phosphorus, respectively. The selenium content ranged from 147 µg/kg in the Bronic and Troy cultivars to 207 µg/kg in the CDC Alma cultivar. However, an unknown cultivar had a selenium content of 308 µg/kg. Regardless of the specific mineral, the composition of minerals in chickpeas was high and can contribute significantly to dietary mineral requirements.

Physical parameters of chickpeas

(Tables 36-39)

Test weight, 1000 seed weight, water hydration capacity, percentage unhydrated seeds, swelling capacity, cooked firmness and color represent the physical parameters used to define physical quality. The data presented includes the range and mean value for 2016 and comparisons to the 5-year mean value.

Test weight ranged from 56-65 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 57 lbs/bu in CDC Alma to 64 lbs/bu in the Bronic cultivar. The range and mean **1000 seed weight** of chickpeas grown in 2016 were 271-590 g and 410 g, respectively (Table 36). The mean value was slightly higher than the 5-year mean of 403 g. The Troy cultivar had a highest 1000 seed weight at 590 g while the Billy Bean cultivar had the lowest value at 286 g (Table 37).

Water hydration capacity of chickpeas ranged from approximately 76-134%, with a mean of 105% (Table 36). The water hydration capacities of chickpeas from 2016 was essentially the same as the 5-year mean of 106%. The Troy cultivar had the highest water hydration capacity (134%) while CDC

Table 36. Physical parameters of chickpeas grown in the USA, 2011-2016.

	Year							
	2016		2015	2014*	2013	2012	2011	5-year
Physical Parameter	**Range**	**Mean (SD)**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean (SD)**
Test Weight (lb/Bu)	56-65	61 (2)	62	61	60	61	61	61 (1)
1000 Seed Wt	271-590	410 (106)	443	376	404	403	387	403 (25)
Water Hydration Capacity (%)	76-134	105 (15)	105	99	108	113	103	106 (5)
Unhydrated Seeds (%)	0-2	1 (1)	1	4	0	0	0	1 (2)
Swelling Capacity (%)	97-173	141 (12)	136	105	**	**	**	nd
Cooked Firmness (N/g)	18.2-30.0	22.0 (3.0)	19.7	**	**	**	**	nd

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

Table 37. Mean physical properties of chickpea cultivars grown in the USA, 2016.

Cultivar	Test Weight (lb/Bu)	1000 Seed Wt	Water Hydration Capacity (%)	Unhydrated Seeds (%)	Swelling Capacity (%)	Cooked Firmness (N/g)
Billy Bean	63	286	116	0	151	21.3
Bronic**	64	351	116	0	166	20.0
CDC Alma**	57	527	76	0	97	18.2
CDC Frontier	61	394	88	1	116	19.5
CDC Orion	61	471	89	1	125	21.0
Sierra	61	497	105	0	141	23.6
Troy**	60	590	134	0	165	28.6
Unknown**	62	271	100	1	173	22.9

**Value from only one sample.

Alma had the lowest (76%) (Table 37). **Unhydrated seed percentage** ranged from 0-2% with a mean of 1%, which was same as the 5-year mean of 1% (Table 36). A number of cultivars had 0% unhydrated seed values and only the cultivar CDC Frontier and CDC Orion had mean values of 1% (Table 37). The **swelling capacity** of chickpeas ranged from 97 to 173%, with a mean value of 141% (Table 36). These values were higher than those reported in 2014 but comparable to chickpeas from 2015. The Bronic cultivar had the greatest swelling capacity at 166% while the CDC Alma cultivar had the lowest (97%). The CDC Frontier cultivar in 2016 had a swelling capacity of 116% while a value of 105 and 138% was observed in this same cultivar in 2014 and 2015, respectively (Table 37). The **cooked firmness** was new for 2015 and thus comparisons are based on two years. The cooked firmness of all chickpea ranged from 18.2 to 30.0 N/g with a mean value of 22.0 N/g (Table 36). The firmness of chickpea from the 2016 crop was slightly firmer than the chickpeas from 2015, which had mean firmness values of 19.7 N/g. Although different, it is unlikely that consumers could detect this small difference. Among the cultivars, CDC Alma had the lowest cooked firmness while Troy was the firmest (Table 37).

Color quality was measured using L*, a, and b values and from these values a color difference was determined on chickpeas before and after soaking (Table 38). **Color quality** indicated that the lightness (i.e., L*) of the chickpeas from 2016 was lower than the chickpea from previous years (Table 38). In 2016, the "a" value of 9.09 was lower than values from 2013, but higher than 2012, 2014 and 2015. This indicates that the chickpeas from 2016 were slightly less red than the 2013 samples, but slightly redder the same as the 2012, 2014 and 2015. The "b" value for chickpeas from 2016 indicated a less yellow color compared to the 2013 and 2015 crops, but yellower than the chickpea from 2012 and 2014 harvest years.

The color of the chickpeas changed after the soaking process. 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 2016 compared to 2014, but more than the change in 2015. This suggests better color stability of the chickpeas from 2015 (Table 38). Among cultivars, Troy had the highest L* value of 62.49 while Bronic had the lowest (i.e. 49.49). In contrast, the Troy cultivar had the lowest yellowness value while the Billy Bean cultivar had the highest among known cultivars (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. The greatest color difference was observed in the Troy cultivar (Table 39). This suggests that the Troy cultivar had the least color stability in the soak test. However, the yellowness of the Troy cultivar came out more in the soaked sample based on visual observations.

Starch properties
(Tables 40-41)

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

Peak, hot and cold paste viscosities of the CDC Frontier chickpea cultivar were greatest among cultivars tested (Table 41). In contrast, Bronic had the lowest Peak, hot and cold paste viscosities. Other starch properties were similar among cultivars tested.

Table 38. Color quality of chickpeas grown in the USA before and after soaking, 2012-2016.

	Mean (SD) Color Values									
	Before Soaking					After Soaking				
Color scale*	2016	2015	2014	2013	2012	2016	2015	2014	2013	2012
L (lightness)	53.01 (3.01)	66.86 (4.22)	63.32 (2.61)	81 (12)	61 (2)	55.57 (1.04)	70.33 (4.07)	60.49 (8.02)	89 (11)	62 (1)
a (red-green)	9.09 (1.72)	7.83 (1.61)	5.55 (0.76)	11 (2)	6 (1)	11.44 (1.04)	6.97 (1.28)	7.01 (0.44)	13 (3)	7 (1)
b (yellow-blue)	21.14 (2.07)	22.19 (2.55)	14.19 (0.45)	28 (4)	15 (1)	34.11 (2.31)	31.47 (7.70)	29.26 (0.91)	53 (7)	26 (2)
Color Difference	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, 2016.

Cultivar	Mean Color Values**						
	Before Soaking			After Soaking			Color Difference
	L	a	b	L	a	b	
Billy Bean	50.76	10.75	23.06	55.84	12.22	35.97	14.04
Bronic*	49.49	10.14	22.11	54.94	12.57	35.99	15.12
CDC Alma*	51.69	8.53	20.30	54.24	11.94	34.84	15.26
CDC Frontier	52.72	9.86	21.74	56.31	11.99	36.32	15.24
CDC Orion	52.78	8.88	21.07	54.79	11.72	33.77	13.26
Sierra	54.49	7.74	19.53	55.30	10.08	31.21	12.11
Troy*	62.49	4.76	16.09	56.37	10.39	31.31	17.45
Unknown*	53.34	10.26	23.44	56.82	12.14	35.67	12.89

* 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. Starch characteristics of chickpeas grown in the USA, 2011-2016.

Starch Characteristic	Year							5-year Mean (SD)
	2016		2015	2014	2013	2012	2011	
	Range	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	
Peak Viscosity (RVU)	121-217	139 (23)	126 (15)	143 (7)	178 (15)	119 (10)	142 (26)	147 (11)
Hot Paste Viscosity (RVU)	114-203	134 (22)	124 (14)	138 (7)	156 (11)	110 (8)	132 (20)	135 (9)
Breakdown (RVU)	1-16	6 (4)	3 (2)	5 (1)	23 (11)	9 (6)	10 (9)	12 (6)
Cold Paste Viscosity (RVU)	161-440	214 (70)	185 (24)	210 (2)	292 (46)	161 (16)	212 (57)	221 (21)
Setback (RVU)	43-238	80 (43)	62 (13)	17 (2)	136 (40)	50 (12)	66 (50)	68 (18)
Peak Time (Minute)	4.93-7.00	6.04 (0.61)	6 (0)	6 (0)	9.9 (1)	10.3 (1)	8 (2)	9 (1)
Pasting Temperature (°C)	71.7-76.8	74.5 (1.3)	76 (2)	74 (3)	*	*	nd	nd

*data not reported in 2013; nd = not determined

Table 41. Mean starch characteristics of chickpea cultivars grown in the USA, 2016.

Cultivar	Peak Viscosity (RVU)	Hot Paste Viscosity (RVU)	Breakdown (RVU)	Cold Paste Viscosity (RVU)	Setback (RVU)	Peak Time (Min)	Pasting Temperature (°C)
Billy Bean	130	123	7	177	54	6	75
Bronic*	127	121	6	164	43	6	77
CDC Alma*	152	147	4	273	126	5	72
CDC Frontier	195	187	8	381	193	6	73
CDC Orion	135	130	5	219	89	5	73
Sierra	133	129	4	196	67	7	75
Troy*	130	128	2	187	60	6	74
Unknown*	126	117	10	168	51	6	75

* Value from only one sample.

Faba Bean Quality

One faba bean samples was evaluated during the 2016 survey. The proximate and mineral data (Table 42) supports similar data to other pulses. The protein content (22.6%) was slightly higher than peas and lentils but significantly higher than protein in chickpeas. Some of the physical parameters (Table 43) were similar to other pulses. The mean 1000 seed weight fell between peas and chickpeas. The cooked firmness tended to be higher than for other pulses. However, the starch pasting properties related to viscosities indicates a less viscous starch slurry compared to other pulses. The color data (Table 44) supports a darker pulse where the L* value is lower than other pulses. Soaking caused an increased blueness in the sample. The color difference between the pre- and post- soaked bean was similar to other pulses. In general, the data on Faba bean suggests similar quality to other pulses. However, given that only one sample was evaluated no clear trends can be established.

Table 42. Proximate composition of Faba bean grown in the USA, 2016.

Proximate Composition**	2016 Mean
Moisture (%)	11
Ash (%)	2.7
Protein (%)	22.4
Starch (%)	40
Calcium (mg/kg)	793
Copper (mg/kg)	7
Iron (mg/kg)	36
Magnesium (mg/kg)	1362
Manganese (mg/kg)	14
Potassium (mg/kg)	6899
Phosphorus (mg/kg)	3097
Zinc (mg/kg)	20
Selenium (μg/kg)	158

*2016 data is for one sample of faba bean;
**composition is on an "as is" basis

Table 43. Physical parameters and starch characteristics of faba bean grown in the USA, 2016.

Physical Parameter	2016* Mean
Test Weight (lb/Bu)	60
1000 Seed Wt	343
Water Hydration Capacity (%)	84
Unhydrated Seeds (%)	0
Swelling Capacity (%)	129
Cooked Firmness (N/g)	30.1

Starch Characteristic	2016* Mean
Peak Viscosity (RVU)	117
Hot Paste Viscosity (RVU)	111
Breakdown (RVU)	6
Cold Paste Viscosity (RVU)	188
Setback (RVU)	77
Peak Time (Minute)	5.53
Pasting Temperature (°C)	75.8

*2016 data is for one sample of faba bean only

Table 44. Color quality of faba bean grown in the USA, 2016, before and after soaking.

	Mean Color Value**	
Color Scale*	Before Soaking 2016	After Soaking 2016
L (lightness)	46.53	49.71
a (red-green)	4.36	5.28
b (yellow-blue)	18.11	15.85
Color Difference#	11.26	

*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; **2016 data is for one sample of faba bean. #color difference = change in value before soaking and after soaking

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, chickpea and faba bean 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 2016 fall within the range of those reported in 2011-2015.

Table 45. Percent recommended daily allowance (RDA) of minerals in a 50 g (dry) serving of pulses based on 2016 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
Faba Bean	14	23	10	9	13	4	17	22	7

*%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)

Author

Dr. Clifford Hall, Professor, Pulse Quality, Plant Sciences, North Dakota State University, Dept. 7670, 210 Harris Hall, P.O. Box 6050, Fargo, ND, USA 58108-6050.

Pulse Quality Technical Team

Mary Niehaus (Food Chemist); **Madison Gohl** (Undergraduate student); **Amber Kaiser** (Graduate student); **Joe Kallenbach** (Graduate student); **David Hinrichs** (Undergraduate student); **Katelyn Schmoll** (Undergraduate student); **David Syverson** (Undergraduate student); **Ruoling Tang** (Graduate student); **Serap Vatansever** (Graduate student).

Funding Support

- Northern Pulse Growers Association
- North Dakota State University Agriculture Experimental Station
- USA Dry Pea and Lentil Council

Acknowledgements

The 2016 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.

References

American Association of Cereal Chemists, 2000. Approved methods of the AACC 10th edition.

National Pulse Quality Survey Report 2010, Northern Crop Institute, Fargo, ND

2011 U.S. Pulse Quality Survey, North Dakota State University, Fargo, ND Northern Pulse Growers Association, http://www.northernpulse.com.

2012 U.S. Pulse Quality Survey, North Dakota State University, Fargo, ND Northern Pulse Growers Association, http://www.northernpulse.com.

2013 U.S. Pulse Quality Survey, North Dakota State University, Fargo, ND Northern Pulse Growers Association, http://www.northernpulse.com.

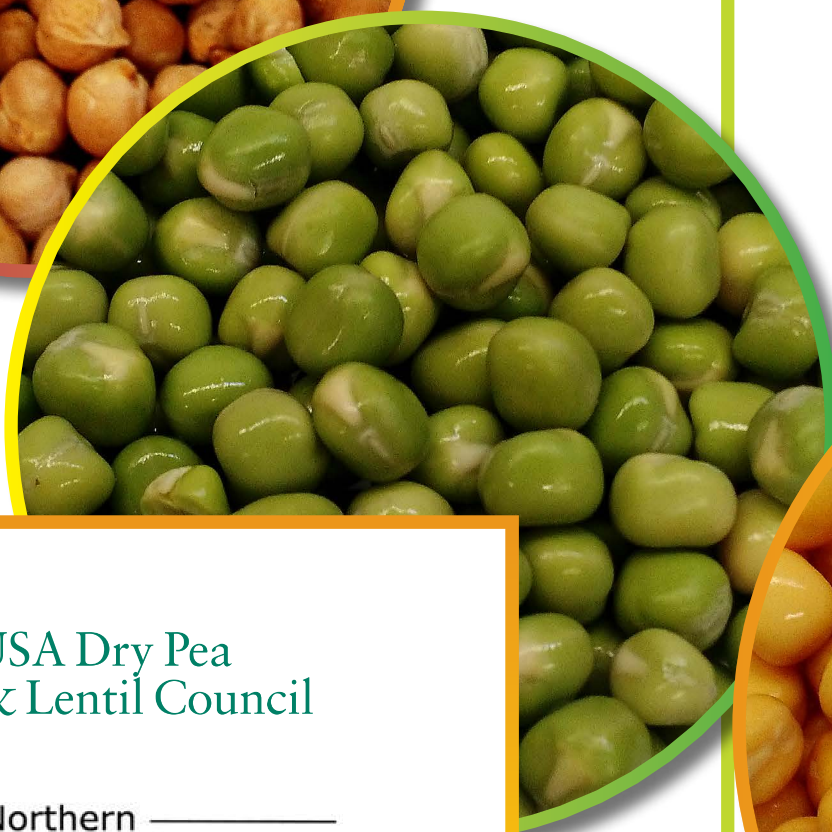
2014 U.S. Pulse Quality Survey, North Dakota State University, Fargo, ND Northern Pulse Growers Association, http://www.northernpulse.com.

2015 U.S. Pulse Quality Survey, North Dakota State University, Fargo, ND Northern Pulse Growers Association, http://www.northernpulse.com.

Thavarajah et al. 2008. Journal of Agricultural and Food Chemistry 56(22), 10747-10753.

Thavarajah et al. 2009. Journal of Agricultural and Food Chemistry 57, 5413-5419.

USA Dry Pea Lentil Council, 2014-2015; http://www.pea-lentil.com/.



USA Dry Pea & Lentil Council

Northern Pulse Growers Association

info@northernpulse.com
www.northernpulse.com

NDSU NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

Dr. Clifford Hall
clifford.hall@ndsu.edu