# 2019 U.S. Pulse Quality Survey

Northern Pulse Growers Association

South Dakota State University
South Dakota Agricultural Experiment Station

USA Dry Pea & Lentil Council

# Contents





# 2019 Overview and Author's Comments

## Summary Points

1. The 2019 pulse quality report represents the 12th variation of a pulse quality evaluation started by the Northern Crops Institute in 2008.
2. Data from approximately 265 samples received from major US pulse growing regions were evaluated.
3. Unlike previous years, similar proximate composition to other specific crop years was observed. Instead, the quality matched different years based on the quality trait evaluated. However, most of the quality traits mirrored the 5-year mean value.
4. A canning quality evaluation was included for the third time in this report for pea and chickpea. The pulses evaluated tended to be less firm but had greater canning water hydration capacity and swelling capacity.
5. A chickpea size distribution was included for the first time. A sieve analysis was not only effective in differentiating small and large chickpea, but also intermediate sized chickpea based on retention on various sieves.
6. Pea and chickpea had high percent moisture in 2019.
7. Marrowfat and winter peas were evaluated for the first time in the 2019 survey.
8. Due to equipment failure, mineral analysis is not included in the current report but will be provided as a separate report at a later date.

This report provides a summary of the 2019 pulse crop quality for dry pea, lentil, and chickpea cultivars grown commercially in the USA. In 2019, a total of 265 pulse samples were collected from the major US pulse growing regions. This number represents the most samples evaluated since the inception of the survey. The seeds evaluated included 183 dry pea, 43 lentil and 39 chickpea, which were acquired from pulses growers and industry representatives in pulse growing areas in Idaho, Montana, North Dakota, South Dakota, Oregon and Washington.

According to the USDA National Agricultural Statistics Service, pulse harvested acreage and estimated total production for 2019 was 1.9 million and 1.7 Million MT, respectively. Pea acreage was up in 2019 compared to 2018 and was comparable to the acres harvested in 2017. In contrast, lentil and chickpea acres were down.

The quality is grouped into three main categories, which include proximate composition, physical parameters and functional characteristics. The canning quality was also a separate category. Proximate quality parameters include ash, fat, mineral, moisture, protein, and total starch content. Water hydration capacity, percentage unhydrated seeds, swelling capacity, cooked firmness, test weight, 1000 seed weight, size distribution and color represent the physical parameters. The pasting characteristics represent the functional characteristics of the pulses.

Results from the proximate (i.e., moisture, protein, etc.) composition analyses indicates that results did not match one specific crop year. Similar to previous years, the 2019 pulse samples varied substantially in composition from other years. The difference might be related to the more diverse pool of samples from different growing locations. The 265 pulse samples evaluated in 2019 came from the most diverse growing regions since the survey was started.

In general, pea and chickpea from 2019 had higher moisture contents compared pulses from other crop years while lentils also tended to have higher moisture percentage that was similar lentils from 2015. All pulses had moisture contents higher than the 5-year mean moisture values. The total starch contents of pea samples were higher than the five-year average while the opposite was true for chickpea. Lentils had total starch percentages that were equal to the 5-year mean percent starch but not any other specific year.

The starch percentages in pea and chickpea most match pulse grown in 2014 and 2016, respectively. The fat contents of the pulses evaluated were within ranges reported in the literature. However, the fat contents of all pulses from 2019 were lower than the fat contents of pulses from previous years. The yellow and green dry pea composition was nearly identical to each other. The yellow peas tended to have lower protein, but higher starch compositions compared to the green peas. However, the yellow pea also had 1.5 percentage points higher moisture than the green peas. Lentils from 2019 had a protein content comparable to lentils from 2018 and higher than protein contents for lentils from previous years. Differences in proximate composition were observed between the three lentil market classes. The green and red market classes had similar protein and starch contents while the Spanish brown market class had lower protein but higher starch content than the other two market classes. Both protein and starch contents were comparable to the 5-year mean values.

The physical parameters such as water hydration capacity, test weight, and color analysis of the 2019 had varying result compared to previous pulse crops. Overall, the test weight of dry peas, lentils and chickpeas were approximately that of the 5-year average. The 1000 seed weight was slightly lower for lentils and higher for pea and chickpea compared to the 5-year mean. The water hydration capacities were slightly lower and equal to the 5-year mean for lentil and for pea and chickpea, respectively. The physical parameters of the 2019 lentils were most comparable to the lentils from 2016 and in a few of the parameters (e.g., swelling capacity) were comparable to the lentils from 2017. Swelling capacity of chickpea from 2019 was comparable to swelling capacity in chickpea from 2015. New in 2019 was a size distribution analysis of chickpea. The percentage of seed being retained on a series of sieves provide a means to differentiate size. Of the chickpea evaluated, 93, 94 and 97% of the seed from Nash, Royal and Dylan cultivars were retained a 22/64-inch sieve. This high percentage supports these as being large chickpea. In contrast, only 19.1% of the Bronic seed were retain on the 22/64-inch sieve, support Bronic as a small chickpea. The color of the pea in 2019 were darker than pea from other harvest years. The darker color was supported by lower lightness (L) and negative "a" (greenness indicator) values. The color difference values of dry peas from 2019 were lower than peas from all other crop years. The color tended to be darker in all lentils regardless of market class.

The starch pasting properties closely matched those of the peas from 2017. The paste that resulted from the 2019 pea flour was less viscous than the paste from the pea flour from the 2016 crop year. The peas from the yellow market class had viscosity properties that were similar to the yellow peas from 2016 while the pasting characteristics of green peas from 2019 closely aligned with pea from 2018. The pasting properties of the lentil flour from the 2019 samples were most like the pasting properties of lentils from 2017. Differences in pasting properties were found between lentil cultivars. The pasting characteristics of all market class exceeded the 5-year mean viscosity values for their respective market class. Unlike pea and lentil, pasting properties of chickpea from 2019 did not mirror the pasting properties of the chickpea from previous years.

The canning evaluation was completed for a third time since the survey inception. Overall, the canning quality of pea and chickpea from 2019 differed from previous evaluations. Water hydration capacity, and swelling capacity of the canned pea were higher than previously reported values. In contrast, canning firmness was lower than in previous evaluations; thus, indicating softer texture. Chickpea from 2019 had higher hydration capacity and swelling capacity but lower canning firmness than their respective quality traits in samples from 2018.

The focus of the pulse program is the quality evaluation and utilization of pulses as food and food ingredients. The mission of the Pulse Quality Program is to provide industry, academic and government personnel with readily accessible data on pulse quality and to provide science-based evidence for the utilization of pulses as whole food and as ingredients in food products.

The data provided has been reported for a number of years. I welcome any thoughts, comment, and suggestions regarding the report. If a quality trait is of interest please reach out to me. I would like to thank the USA pulse producers for their support of this survey.

Sincerely,

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The Northern Plains region and Pacific Northwest are the largest pulse producing area within the USA. US pulse harvested acreage in 2019 was 1,887,000 (USDA 2019; Table 1), which was approximately 360 thousand less acres than in 2018. Total US pulse production (Metric Tons (MT) in 2019 is estimated to be 1,725,806, which is up from the 1,460,378 produced in 2018, but down from the high of 1,927,285 from 2016. The conditions affecting the pulse growing regions likely contributed to the lower production compared to 2016 since some field were not harvested due to inclement weather at the time of harvest. Pulse production was higher than the 1,113,245 MT produced in 2015.

The UDSA (2019) estimated that the dry pea acreage was 1,052,000, which was down from the 1,334,800 in 2016 (Table 1). Pea production (1,135,229 MT) was comparable to the 2016 production (1,228,282 MT) despite having less harvested acres (Table1). Lentil acreage was 431,000 compared to 758,000 in 2018, 957,000 in 2017, 917,000 acres in 2016, and 476,000 in 2015 (USDA; Table 1). Lentil production (273,723 MT) in 2019 lower than 398,572 MT in 2018, 380,905 MT in 2017 and 564,087 MT in 2016.However, the 2019 production was comparable to 2015.

Chickpea harvested acres (404,000) in 2019 was lower than the 651,300 acres in 2018, 476,300 acres in 2017 and significantly higher than the 277,500 in 2016, and 203,100 in 2015, (USDA 2019). Production was estimated at 316,854 in 2019, which is lower than the 425,870 MT in 2018, but higher than the 234 thousand MT in 2017 and was substantially higher than the 135,016 MT and 98,817 MT in 2016 and 2015, respectively.

The increased production of the pulses supports increased yields per acres. In 2019, the mean pea yield was 2,124 lb/acre while in 2018 the yield was 1,972 lb/acre and in 2017 the yield was1,372 lb/acre. Lentil yields in 2019 were 1,250 which is a significant improvement over the 1,149 and 877 lb/acre yields in 2018 and 2017, respectively. Chickpea yields were 1,544 in 2019 and 1,437 and 1,106 lb/acre in 2018 and 2017, respectively.

**Table 1. United states pulses acreage and production summary for 2015-2019.**

| Crop | 2019 Acreage* | 2019 Production** | 2018 Acreage* | 2018 Production** | 2017 Acreage | 2017 Production** | 2016 Acreage | 2016 Production** | 2015 Acreage | 2015 Production** |
|---|---|---|---|---|---|---|---|---|---|---|
| Dry Peas | 1,052,000 | 1,135,229 | 836,400 | 635,936 | 1,108,900 | 648,251 | 1,334,800 | 1,228,282 | 1,083,500 | 738,203 |
| Lentil | 431,000 | 273,723 | 758,000 | 398,572 | 957,000 | 380,905 | 917,000 | 564,087 | 476,000 | 276,225 |
| Chickpea | 404,000 | 316,854 | 651,300 | 425,870 | 476,300 | 238,975 | 277,500 | 135016 | 203,100 | 98,817 |
| Total | 1,887,000 | 1,725,806 | 2,245,700 | 1,460,378 | 2,542,200 | 1,304,132 | 2,529,300 | 1,927,385 | 1,762,600 | 1,113,245 |

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

# Laboratory Methods Used to Measure Pulse Quality

Where applicable, standard methods were followed for the determination of each pulse quality attribute in 2019 (Table 2).The fat (i.e. lipid) content and canning methods were added in 2017. These methods were again evaluated in 2019. For most other analyses, data is provided on data collected between 2013 and 2018. The data is report as a range, mean and standard deviation (SD) for the 2019 harvest year while preceding years were provided as a means plus SD. Data on cultivar was reported only for the 2019 harvest years and no comparisons were made in the tables to cultivar from the previous year. A summary of the testing methods can be found in Table 2. Further discussion of the testing methods is provided below.

- Moisture content is the quantity of water (i.e. moisture present in a sample and is expressed as a percentage. Moisture content is an important indicator of pulse seed handling and storability. Generally, pulse crops are recommended for harvest at 13-14% moisture. At lower moisture levels, the seeds are prone to mechanical damage such as fracturing. Pulses with higher moisture levels are more susceptible to enzymatic activity and microbial growth, which dramatically reduce quality and increase food safety risks.

- Pulses are rich in protein, which ranges from 20 to 30% depending on the growing location, cultivar, and year. Pulses are low in sulfur-containing amino acids but high in lysine, an essential amino acid for human health. Protein content is the quantity of protein present in a sample and is expressed as a percentage.

- The fat (i.e. lipid) content is the quantity of fat present in the pulse. Usually, pea and lentil have fat contents under 3% while chickpea contains 5-10%.

- Ash content is the quantity of ash present in a sample and is expressed as a percentage. Ash is an indicator of minerals. Higher ash content indicates higher amounts of mineral such as iron, zinc, and selenium. The specific mineral analysis provides information in mg/kg levels.

- Total starch is a measure of the quantity of starch present in a sample and is expressed as a percentage. Starch is responsible for a significant part of the pulse functionality such as gel formation and viscosity enhancement.

- Enzymatic hydrolysis is the basis for the starch determination. Starch functionality is measured using the RVA instrument. Pulses show a type C pasting profile, which is represented by a minimally definable pasting peak, a small breakdown in viscosity and high final peak viscosity. This type of starch is ideal for glass noodle production.

- Test weight and 1000 seed weight are indicators of seed density, size, shape, and milling yield. Each pulse crop has its own market preference based on color, seed size, and shape. A grain analysis computer (GAC 2100) is used to determine test weight in lbs/bu.

- Water hydration capacity, percentage unhydrated seeds, and swelling capacity are physical characteristics of pulses that relate to the ability of the pulse to re-hydrate. The swelling capacity relates to the increased size of the pulse as a result of rehydration. Cooking firmness provides information on the texture (i.e. firmness) of the pulse after a cooking process. The data obtained can be used to predict how a pulse might change during cooking and canning processes.

- Color analysis is provided as L*, a and b values. The color analysis is important as it provides information about general pulse color and color stability during processing. Color difference is used specifically to indicate how a process affects color. In this report, a color difference between pre- and post-soaked pulses was determined. "L*" represents the lightness on a scale where 100 is considered a perfect white and 0 for black. Pulses such as chickpeas and yellow peas typically have higher L* values than green or red pulses. The "a" value represents positive for redness and negative for green and "b" represents positive for yellow, negative for blue and zero for gray. A pulse with a higher positive "b" value would be indicative of a yellow pulse while a higher "a" value represents a pulse with a red-like hue, thus brown pulses have a higher red value than a yellow pulse. Green pulses have negative "a" values and thus the greater the negative value, the greener the pulse



- Canning quality evaluation. This evaluation serves as an Indicator of pulse quality after a canning process and a three-week storage. The information allows for a relative difference in quality to be established following a canning process that used a brine solution containing calcium chloride.

**Table 2. Quality attribute, analytical method, and remarks for analyses conducted for the 2019 pulse quality survey.**

| Quality Attribute | Method | Remarks |
|---|---|---|
| 1. Moisture (%) | AACC International method 44-15A | Indicator of post-harvest stability, milling yield and general processing requirements. |
| 2. Protein (%) | AACC International method 46-30 | Indicator of nutritional quality and amount of protein available for recovery. |
| 3. Ash (%) | AACC International method 08-01 | Indicator of total non-specific mineral content. |
| 4. Total starch (%) | AACC International method 76-13 | Indicator of nutritional quality and amount of starch available for recovery. |
| 5. Fat (Lipid) | AOCS Method Ba 3-38 | Indicator of nutritional quality as related to the amount of fat in the samples. |
| 6. Minerals | Thavarajah et al., 2008, 2009 | Indicator of nutritional quality as related to specific minerals. |
| 7. Test weight (lb/bu) | AACC International method 55-10 | Indicator of sample density, size, and shape. |
| 8. 1000 seed weight (g) | 100-kernel sample weight times 10 | Indicator of grain size and milling yield. |
| 9. Chickpea Size Determination | Four samples of 250 seeds of chickpea were placed on a series of sieves (22/64", 20/64", 18/64") and rotated. The number of seed retain on each sieve was determined and reported as % of seed retained. | Indication of the size distribution within a sample of chickpea. |
| 10. Water hydration capacity (%) | AACC International method 56-35.01 | Indicator of cooking and canning behavior. |
| 11. Unhydrated seed (%) | AACC International method 56-35.01 | Indicator of cooking and canning behavior and the amount of seed that may not rehydrate. |
| 12. 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. |
| 13. 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. |
| 14. Color difference ($\Delta E^*ab$) | 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. |
| 15. 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. |
| 16. 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. |
| 17. Canning Quality | Followed methods associated with quality attributes 9, 11, 13 and 15. Canning was completed in laminated metal cans using calcium chloride brine and processing 20 minutes and 20 psi. | Indicator of pulse quality after a canning process and 3-week storage. The information allows for a relative difference in quality to be established following a canning process that used a brine solution containing calcium chloride. |

# Dry Pea Quality

## Sample Distribution

A total of 183 dry pea samples were collected from Idaho, Montana, North Dakota, Oregon, South Dakota and Washington from July to November 2019. Growing location, number of samples, market class, and genotype details of these dry pea samples were recorded (Table 3). The majority of the peas were obtained from Montana and North Dakota. Green peas accounted for 58 of the samples collected, where Arcadia (18), Banner (6), Ginny (5), CDC Greenwater (4) and Greenwood (5) accounted for the majority of the green peas evaluated. The remaining samples were a mix of various cultivars (Table 3). Yellow peas accounted for 120 of the pea samples collected, where Salamanca (26), Nette (16) Agassiz (9), Treasure (6), Durwood (5) and AC Earlystar (5) cultivars accounted for the majority of the yellow pea samples evaluated. Like green peas, the remaining samples were a mix of various cultivars (Table 3). Marrowfat (1) and Winter (4) were also evaluated in 2019. A significant number (31) were not identified by cultivar name and were listed as unknown in the data.

## Proximate Composition of Dry Pea

### Moisture

The moisture content of dry pea ranged from 8.2-16.2% in 2019 (Table 4). The mean moisture content of all 183 pea samples was 12.4%, which is higher than the 5-year mean of 10.2%. Dry peas grown in 2019 had the highest moisture contents compared to pea from previous harvest years. The moisture content is lower than the 14% recommended for general storability; however, long term storage under dry conditions could reduce seed moisture to lower levels where damage during storage and handling could occur. In 2019, approximately 25 samples had moisture contents greater than 14%.

The moisture contents of the green and yellow market classes were different by approximately 1.4 percentage points (Table 5). The green and yellow seed moisture of 11.5 and 12.9%, respectively, were approximately the same values from pea samples

**Table 3. Description of dry pea samples used in the 2019 pulse quality survey.**

| State | No. of Samples | Market Class | Cultivars | |
|---|---|---|---|---|
| Idaho | 16 | Green | Banner | Greenwood |
| | | | Pro 131-7123 | |
| | | Winter | Austrian winter | Vail |
| Montana | 57 | Green | AAC Comfort | Aragorn |
| | | | Arcadia | CDC Greenwater |
| | | | Ginny | Greenwood |
| | | | Hampton | Majoret |
| | | Yellow | AAC Carver | AAC Profit |
| | | | AC Agassiz | AC Earlystar |
| | | | Bridger | CDC Amarillo |
| | | | CDC Inca | CDC Meadow |
| | | | CDC Saffron | CDC Spectrum |
| | | | Delta | DL Apollo |
| | | | DS Admiral | Durwood |
| | | | Hyline | Jetset |
| | | | Korando | LG Amigo |
| | | | LG Sunrise | Navarro |
| | | | Nette 2010 | Salamanca |
| | | | Spider | Treasure |
| | | Marrowfat | Orka | |
| North Dakota | 101 | Green | Arcadia | CDC Greenwater |
| | | | Empire | Greenwood |
| | | | Majoret | Shamrock |
| | | Yellow | AAC Chrome | AAC Profit |
| | | | AC Agassiz | AC Earlystar |
| | | | CDC Amarillo | CDC Golden |
| | | | Durwood | Inca |
| | | | Montech 4152 | Mystique |
| | | | NDP121587 | Nette 2010 |
| | | | Salamanca | Spectrum |
| | | | Spider | Summit |
| | | | SW Midas | Treasure |
| Oregon | 1 | Green | Ariel | |
| South Dakota | 2 | Yellow | AAC Profit | |
| Washington | 6 | Green | Columbian | Ginny |
| | | | Hampton | |
| | | Winter | Vail | |



### Ash

Ash content of dry pea ranged from 1.8-2.9%, with a mean of 2.4%. The mean ash content of dry peas grown in 2019 was less than the 5-year mean (Table 4). Only the peas from the 2014 harvest year had a lower ash content. Ash content is a general indicator of minerals present. The ash contents of yellow and green market classes were both 2.4% (Table 5). The green and yellow pea ash contents were similar to their respective 5-year mean value of 2.4 and 2.5%. Some variability in ash content was observed among cultivars (Table 6). Less variability in ash percentage was observed 2019. The ash ranged from 1.9% (LG Amigo) to 2.7% (Empire).

**Table 4. Proximate composition of dry pea grown in the USA, 2014-2019.**

| Proximate Composition (%)* | Year | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2019 | | 2018 | 2017 | 2016 | 2015 | 2014 | 5-year |
| | Range | Mean (SD) | Mean (SD) | Mean (SD) | Mean (SD) | Mean (SD) | Mean (SD) | Mean (SD |
| Moisture | 8.2-16.2 | 12.4 (1.7) | 9.6 (1.0) | 9.5 (1.1) | 10.1 (1.0) | 10.9 (1.5) | 11.3 (1.3) | 10.2 (0.6) |
| Ash | 1.8-2.9 | 2.4 (0.2) | 2.5 (0.2) | 2.5 (0.2) | 2.5 (0.2) | 2.5 (0.2) | 2.3 (0.2) | 2.5 (0.1) |
| Fat | 0.8-3.5 | 2.0 (0.4) | 2.8 (0.8) | 2.1 (0.7) | ** | ** | ** | nd |
| Protein | 16.6-26.3 | 21.0 (1.4) | 21.4 (1.6) | 21.5 (1.8) | 20.8 (1.6) | 20.3 (1.7) | 22.5 (1.3) | 21.5 (1.1) |
| Total Starch | 39.4-47.3 | 43.3 (1.5) | 42.5 (1.9) | 41.9 (2.0) | 42.8 (3.1) | 41.7 (4.0) | 43.6 (2.1) | 42.7 (0.8) |

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

**Table 5. Proximate composition of different market classes of dry pea grown in the USA, 2014-2019.**

| Proximate Composition (%)* | Mean (SD) of green pea | | | | | | 5-year |
|---|---|---|---|---|---|---|---|
| | 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | Mean (SD) |
| Moisture | 11.5 (1.8) | 9.2 (1.1) | 9.0 (1.1) | 9.6 (0.9) | 10 (1) | 11 (1) | 9.8 (0.8) |
| Ash | 2.4 (1.8) | 2.5 (0.2) | 2.5 (0.2) | 2.4 (0.2) | 2.5 (0.2) | 2.3 (0.2) | 2.4 (0.1) |
| Fat | 2.1 (0.3) | 2.9 (0.8) | 2.1 (0.7) | ** | ** | ** | nd |
| Protein | 21.3 (0.2) | 22.0 (1.8) | 21.6 (2.0) | 21.0 (1.8) | 21 (2) | 23 (1) | 21.8 (0.8) |
| Total Starch | 43.1 (1.5) | 42.3 (1.6) | 41.4 (2.1) | 42.1 (2.9) | 41 (3) | 44 (2) | 42.2 (1.2) |
| **Proximate Composition (%)*** | **Mean (SD) of yellow pea** | | | | | | **5-year** |
| | **2019** | **2018** | **2017** | **2016** | **2015** | **2014** | **Mean (SD)** |
| Moisture | 12.9 (1.4) | 9.9 (0.9) | 9.8 (0.9) | 10.5 (0.9) | 11.5 (1.1) | 12 (1) | 10.6 (0.9) |
| Ash | 2.4 (1.2) | 2.5 (0.2) | 2.5 (0.2) | 2.6 (0.2) | 2.4 (0.2) | 2.4 (0.1) | 2.5 (0.1) |
| Fat | 1.9 (0.4) | 2.7 (0.8) | 2.2 (0.8) | ** | ** | ** | nd |
| Protein | 20.8 (0.2) | 21.1 (1.5) | 21.4 (1.7) | 20.6 (1.5) | 19.9 (1.7) | 22 (1) | 21.0 (0.8) |

## Fat (Lipid)

Fat content of dry pea ranged from 0.8 to 3.5%, with a mean of 2.0%. The 2019 evaluation represents the third year of the fat analysis for the pea samples. Thus, no long-term data is available for comparison. However, the mean fat content of pea harvested in 2019 was comparable to the pea harvested in 2017 (2.1%) but was significantly lower than values observed in 2018 (2.8%). The fat contents of the green and yellow market classes were approximately the same (Table 5). Again, the fat percentage for each market class mirrored those of values observed in 2017. Ariel (green) and DL Apollo (yellow) had the highest fat contents in their respective market classes (Table 6). In contrast, AAC Comfort (green) and AAC Chrome and DS Admiral (yellow) had the lowest fat contents among their respective market classes. DS Admiral also had the lowest fat content of the pea samples grown in 2018.

## Protein

Protein content of dry pea ranged from 16.6 to 26.3% with a mean of 21.0%. The mean protein content was comparable to the peas from the 2016 crop year but less than 0.5 percentage points lower than protein observed in the peas from the 2017 and 2018 crop years. The mean protein content of dry peas grown in 2019 was lower than the 5-year mean of 21.5%. The lower protein might be due to the higher moisture contents of the pea evaluated. Furthermore, a greater number of samples were evaluated in 2019 compared to other years and thereby causing more variability in protein content. The mean protein content of the green pea was 0.5 percentage points higher than the mean protein content of the yellow pea. Similar trends in protein data between market classes were observed in prior harvest years (Table 5). Green pea samples had mean protein content of 21.3% while the 5-year mean value was 21.8%. Yellow peas had a mean protein content (20.8%), which was similar to the 5-year mean value (21.0%). Pro 131-7123 (green, 24.5%) and Delta (yellow, 22.8%) cultivars had the highest protein contents in their respective market classes (Table 6). In contrast, Arcadia, Ariel and CDC Greenwater (green) and Spider (yellow) had the he lowest protein percentages among their respective market classes.

**Table 6. Mean proximate composition of dry pea cultivars grown in the USA in 2019.**

| Market Class | Cultivar | Concentration (%) Moisture | Ash | Fat | Protein | Starch |
|---|---|---|---|---|---|---|
| Green | AAC Comfort* | 11.2 | 2.2 | 1.6 | 23.6 | 44.6 |
| | Aragorn* | 10.8 | 2.2 | 2.5 | 21.5 | 45.6 |
| | Arcadia | 12.9 | 2.4 | 2.0 | 20.4 | 43.6 |
| | Ariel* | 9.9 | 2.4 | 3.0 | 20.4 | 46.3 |
| | Banner | 10.1 | 2.3 | 2.3 | 20.6 | 42.1 |
| | CDC Greenwater | 13.0 | 2.3 | 2.1 | 20.4 | 43.2 |
| | Columbian* | 8.2 | 2.5 | 2.1 | 22.2 | 42.4 |
| | Empire* | 12.6 | 2.7 | 2.1 | 21.4 | 42.1 |
| | Ginny | 10.6 | 2.3 | 2.1 | 20.6 | 44.3 |
| | Greenwood | 10.4 | 2.4 | 2.2 | 22.7 | 42.5 |
| | Hampton | 10.4 | 2.3 | 2.1 | 21.4 | 42.3 |
| | Majoret | 11.7 | 2.2 | 1.8 | 22.6 | 43.0 |
| | Pro 131-7123 | 8.9 | 2.5 | 1.9 | 24.5 | 41.1 |
| | Shamrock | 12.9 | 2.6 | 2.0 | 21.6 | 43.1 |
| Yellow | AAC Carver | 11.8 | 2.3 | 2.3 | 20.4 | 44.0 |
| | AAC Chrome* | 12.8 | 2.5 | 1.2 | 21.3 | 44.0 |
| | AAC Profit | 13.4 | 2.3 | 1.6 | 22.4 | 43.0 |
| | AC Agassiz | 13.4 | 2.3 | 2.0 | 20.8 | 43.7 |
| | AC Earlystar | 12.2 | 2.4 | 1.9 | 19.3 | 44.3 |
| | Bridger* | 11.4 | 2.3 | 2.5 | 21.0 | 44.2 |
| | CDC Amarillo | 11.9 | 2.2 | 1.9 | 21.0 | 43.9 |
| | CDC Golden* | 13.4 | 2.3 | 2.1 | 19.7 | 44.0 |
| | CDC Inca | 12.8 | 2.2 | 1.9 | 21.6 | 43.7 |
| | CDC Meadow* | 12.9 | 2.3 | 2.0 | 21.2 | 42.8 |
| | CDC Saffron* | 10.9 | 2.2 | 2.2 | 20.8 | 44.6 |
| | CDC Spectrum | 11.2 | 2.2 | 2.2 | 21.9 | 44.4 |
| | Delta* | 11.3 | 2.1 | 2.3 | 22.8 | 44.2 |
| | DL Apollo* | 11.5 | 2.4 | 2.9 | 21.6 | 46.4 |
| | DS Admiral* | 10.9 | 2.0 | 1.2 | 20.1 | 44.9 |
| | Durwood | 12.3 | 2.3 | 2.4 | 21.2 | 43.7 |
| | Hyline* | 11.2 | 2.4 | 2.4 | 20.8 | 44.7 |
| | Jetset* | 10.2 | 2.1 | 2.2 | 22.3 | 43.6 |
| | Korando | 12.1 | 2.3 | 2.0 | 21.1 | 42.2 |
| | LG Amigo* | 10.7 | 1.9 | 2.3 | 22.0 | 45.1 |
| | LG Sunrise* | 10.7 | 2.2 | 1.9 | 21.5 | 45.8 |
| | Montech 4152* | 12.8 | 2.5 | 1.3 | 21.4 | 42.7 |
| | Mystique | 14.3 | 2.3 | 1.9 | 20.7 | 42.6 |
| | Navarro* | 11.2 | 2.3 | 2.5 | 22.2 | 45.8 |
| | NDP121587* | 12.4 | 2.3 | 1.8 | 20.9 | 43.9 |
| | Nette 2010 | 12.9 | 2.4 | 1.9 | 20.6 | 43.1 |
| | Salamanca | 13.7 | 2.5 | 1.8 | 21.1 | 42.4 |
| | Spider | 12.5 | 2.4 | 2.1 | 18.9 | 43.7 |
| | Summit* | 13.3 | 2.5 | 2.0 | 19.7 | 46.3 |
| | SW Midas | 13.4 | 2.3 | 2.1 | 20.7 | 43.2 |
| | Treasure | 13.3 | 2.4 | 1.8 | 20.1 | 43.5 |
| | Unknown | 12.7 | 2.3 | 1.7 | 21.1 | 43.8 |
| Winter | Austrian Winter | 9.4 | 2.5 | 1.8 | 21.5 | 41.8 |
| | Vail | 9.7 | 2.5 | 2.0 | 21.1 | 43.2 |
| Marrowfat | Orka* | 14.1 | 2.8 | 1.8 | 21.6 | 39.4 |

*Only one sample of cultivar tested

## Total Starch

Total starch content of dry pea ranged from 39.4 to 47.3% with a mean of 43.3%. The mean total starch content of dry peas grown in 2019 was comparable to dry peas from the 2014 harvest year (i.e. 43.6%) and was higher than the 5-year mean of 42.7%. The starch contents of the green and yellow market classes were 43.1 and 43.4%, respectively (Table 5).

Green peas had a mean starch content that was higher than the 5-year mean value of 42.2%. Furthermore, the starch content of peas from 2019 most closes match the starch content of peas from 2016. The 5-year mean starch value for the yellow peas also was lower (42.5%) than the mean starch content (43.4%) of yellow peas harvested in 2019. Like green peas, the peas from the 2016 most closely matched the peas harvested in 2019. Ariel had the highest (46.3%) starch content among the green peas while DL Apollo had the highest starch content (46.4%) in yellow peas. In 2018, Ariel also had the highest starch content among the green cultivars tested. Pro 131-7123 (41.1%) and Korando (42.2%) had the lowest starch contents in green and yellow peas, respectively (Table 6). In 2019, winter pea ad marrowfat pea samples were evaluated. The winter peas had lower percent moisture and higher percent ash than most other pea samples. The protein tended to be higher in both the winter and marrowfat samples compared to the average protein content for all peas. Conversely, the starch tended to be lower in the winter and marrowfat samples.

# Physical Parameters of Dry Pea

Test weight ranged from 60 to 68 lbs/ bu with a mean of 64.3 lbs/bu. This mean value was approximately 1.3 lb/bu higher than the 5-year mean of 63 lbs/bu (Table 7). The test weight for all pea samples harvested in 2019 was most comparable to those from 2015. The test weights of peas in the green and yellow market classes were 64 and 65 lb/bu, respectively (Table 8).

These values were approximately 1 to 2 lb/bu higher than the 5-year mean values. This data supports a denser or heavier pea. The test weight of individual cultivars was comparable to one another within green and yellow market classes (Table 9). Majoret (green) and CDC Golden (yellow) had the highest test weights in their respective market classes. The lowest test weights were 62.5 and 62.8 lb/bu for the Pro 131-7123 (green) and CDC Inca (yellow), respectively (Table 9).

The range and mean 1000 seed weight of dry peas grown in 2019 were 119-333 g and 224 g, respectively (Table 7). The mean value (224g) was higher than the mean 1000 seed weight of peas evaluated in the 2014 to 2018 except for 2016. Peas of the green market class had a mean 1000 seed weight of 207 g, which is slightly higher than the 5-year mean value of 204 g (Table 8). Peas of the yellow market class had a mean 1000 seed weight of 233 g, which is the 13 grams higher than the 5-year mean 1000 seed weight (Table 8). The 1000 seed weight for pea from 2019 were comparable to the peas from 2016. The individual cultivars (Table 9) varied extensively in 1000 seed weight, where the cultivars in the green market class varied (152 to 268 g) were lower than cultivars in the yellow market class (191 to 292 g). Pro 131-7123 (152 g) and CDC Meadow (191 g) and Arcadia (268 g) and Salamanca (292 g) had the lowest and highest 1000 seed weight in the green and yellow market class, respectively (Table 9). In 2018, Salamanca (283 g) also had the highest 1000 seed weight. Although an individual sample of Salamanca had the highest 1000 seed weight, the highest mean 1000 seed weight was observed in the Korando cultivar. The test weight and 1000 seed weight support that the peas from 2019 were larger than the peas from previous crop years with only a few exceptions.

**Table 7. Physical parameters of dry pea grown in the USA, 2014-2019.**

| Physical Parameter | Year 2019 Range | 2019 Mean (SD) | 2018 | 2017 Mean | 2016 Mean | 2015 Mean | 2014 Mean | 5-year Mean (SD) |
|---|---|---|---|---|---|---|---|---|
| Test Weight (lb/bu) | 60-68 | 64.3 (1) | 63.5 (1) | 63 (2) | 63 (4) | 64 (2) | 63 (2) | 63 (1.0) |
| 1000 Seed Wt (g) | 119-333 | 224 (31) | 211 (33) | 204 (32) | 224 (29) | 215 (36) | 216 (27) | 214 (7) |
| Water Hydration Capacity (%) | 61-112 | 96 (8) | 103 (8) | 104 (14) | 97 (6) | 102 (16) | 102 (5) | 103 (5) |
| Unhydrated Seeds (%) | 0-18 | 2 (3) | 1 (2) | 2 (2) | 2 (3) | 2 (2) | 2 (1) | 2 (0) |
| Swelling Capacity (%) | 104-174 | 145 (13) | 147 (14) | 148 (10) | 137 (16) | 152 (17) | 152 (8) | 147 (6) |
| Cooked Firmness (N/g) | 11-53 | 21.0 (7) | 21.0 (5) | 24 (6) | 23 (5) | 21 (6) | * | nd |

*data not reported; nd = not determined

**Table 8. Physical parameters of different market classes of dry pea grown in the USA, 2014-2019.**

| Physical Parameter | Mean (SD) of green pea 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 5-year Mean (SD) |
|---|---|---|---|---|---|---|---|
| Test Weight (lb/bu) | 64 (1) | 63 (1) | 63 (2) | 63 (6) | 63 (2) | 63 (2) | 63 (0) |
| 1000 Seed Wt (g) | 207 (28) | 192 (28) | 190 (28) | 213 (29) | 207 (43) | 219 (21) | 204(13) |
| Water Hydration Capacity (%) | 99 (6) | 106 (8) | 107 (20) | 100 (6) | 114 (11) | 100 (6) | 105 (6) |
| Unhydrated Seeds (%) | 1 (1) | 0 (1) | 2 (2) | 1 (1) | 2 (2) | 1.0 (1) | 1 (1) |
| Swelling Capacity (%) | 144 (10) | 149 (12) | 146 (11) | 140 (16) | 142 (23) | 150 (13) | 143 (4) |
| Cooked Firmness (N/g) | 18.9 (4.6) | 19.8 (5) | 22 (5) | 23 (5) | 17 (5) | * | nd |
| **Physical Parameter** | **Mean (SD) of yellow pea 2019** | **2018** | **2017** | **2016** | **2015** | **2014** | **5-year Mean (SD)** |
| Test Weight (lb/bu) | 65 (1) | 64 (1) | 63 (1) | 63 (2) | 64 (1) | 62 (2) | 63 (1) |
| 1000 Seed Wt (g) | 233 (25) | 222 (31) | 214 (30) | 231 (27) | 220 (32) | 211 (38) | 220 (8) |
| Water Hydration Capacity (%) | 94 (8) | 102 (8) | 102 (5) | 95 (6) | 110 (18) | 99 (13) | 102 (6) |
| Unhydrated Seeds (%) | 2 (4) | 0 (2) | 1 (1) | 2 (4) | 2 (2) | 2.0 (2) | 1 (1) |
| Swelling Capacity (%) | 145 (14) | 146 (14) | 150 (9) | 135 (16) | 147 (14) | 149 (13) | 145 (6) |
| Cooked Firmness (N/g) | 22.0 (7.1) | 21.7 (5) | 25 (6) | 22 (5) | 22 (6) | * | nd |

*data not reported; nd = not determined

**Water Hydration Capacity** of dry peas ranged from 61 to 112%, with a mean of 96% (Table 7). The 2019 mean value is comparable to the water hydration capacity of peas from 2016. Peas from individual harvest years had slightly higher hydration capacity compared to 2019. The mean water hydration capacity of peas in the green market class was five percentage points higher than the mean hydration capacity of the yellow market class (Table 8). The water hydration capacities in the peas from 2019 were comparable to peas from 2014 and 2016 but lower than the 5-year mean water hydration capacity of the green market class. The yellow peas from 2019 had hydration capacities most similar to the peas from the 2016 harvest year. In the green market class, Majoret and Pro 131-7123 had the lowest (91%) and highest (106%) water hydration capacities, respectively. The water hydration capacity ranged from 70% in CDC Meadow (yellow) to 108% in Montech 4152 (yellow) cultivars (Table 9). Marrowfat pea had the highest water hydration capacity (110%) of the pea samples.

**Unhydrated seed percentage** ranged from 0-18% with a mean of 2%, which equals the 5-year mean unhydrated seed percentage (Table 7). Peas from the both market classes had unhydrated seed values of 1 to 2% (Table 8). Both market classes had comparable unhydrated seed percentages as the 5-year mean value (Table 8). The majority of the green pea cultivars had unhydrated seed rates of 0% while Hampton had unhydrated seed rate of 2% (Table 9). CDC Golden, SW Midas and CDC Meadows had unhydrated seed rates of 12, 12 and 15%, respectively. Overall, the low numbers (0-1%) suggest that no issues should occur during rehydration of the peas.

The **swelling capacity** is the amount of swelling that occurred during rehydration of the dry pea. The swelling capacity of all peas ranged from 104% to 174% with a mean value of 145% (Table 7). The mean swelling capacity for peas from the 2019 harvest was similar to the values obtained in 2017 and 2018 but was slightly lower than peas from the 2014 and 2015 harvest years. The swelling capacity of green peas was about 1 percentage point lower than the yellow pea market class (Table 8), which is the opposite of that observed in 2018, but similar to the observation in 2015 and 2017. Variability in the swelling capacity among cultivars was observed (Table 9). Hampton (green) and SW Midas (yellow) had the least swelling capacity while Shamrock (green) and Montech 4152 (yellow) had the highest swelling capacities among the cultivars tested (Table 9).



**Table 9. Mean physical parameters of USA dry pea cultivars grown in 2019.**

| Market Class | Cultivar | Test Weight (lb/bu) | 1000 Seed Weight (g) | Water Hydration Capacity (%) | Unhydrated Seeds (%) | Swelling Capacity (%) | Cooked Firmness (N/g) |
|---|---|---|---|---|---|---|---|
| Green | AAC Comfort* | 63.9 | 238 | 104 | 0 | 162 | 17.3 |
| | Aragorn* | 63.6 | 215 | 104 | 0 | 135 | 18.3 |
| | Arcadia | 64.5 | 221 | 95 | 1 | 139 | 24.1 |
| | Ariel* | 63.8 | 191 | 95 | 0 | 126 | 20.4 |
| | Banner | 64.2 | 184 | 102 | 0 | 147 | 17.4 |
| | CDC Greenwater | 63.9 | 206 | 103 | 0 | 152 | 18.5 |
| | Columbian* | 64.2 | 203 | 103 | 0 | 145 | 19.9 |
| | Empire* | 63.2 | 220 | 95 | 1 | 141 | 12.8 |
| | Ginny | 62.8 | 192 | 103 | 0 | 141 | 16.8 |
| | Greenwood | 63.3 | 187 | 101 | 0 | 145 | 17.6 |
| | Hampton | 63.3 | 205 | 97 | 2 | 136 | 25.2 |
| | Majoret | 64.7 | 240 | 91 | 1 | 138 | 17.0 |
| | Pro 131-7123 | 62.5 | 157 | 106 | 0 | 149 | 20.6 |
| | Shamrock | 62.7 | 241 | 102 | 0 | 163 | 13.2 |
| Yellow | AAC Carver | 65.3 | 229 | 93 | 3 | 144 | 23.9 |
| | AAC Chrome* | 63.9 | 219 | 99 | 0 | 147 | 17.2 |
| | AAC Profit | 64.0 | 241 | 95 | 0 | 145 | 17.4 |
| | AC Agassiz | 64.6 | 232 | 96 | 0 | 149 | 16.2 |
| | AC Earlystar | 65.3 | 204 | 100 | 1 | 151 | 16.7 |
| | Bridger* | 64.9 | 209 | 103 | 0 | 140 | 26.6 |
| | CDC Amarillo | 64.4 | 211 | 98 | 1 | 133 | 22.7 |
| | CDC Golden* | 66.0 | 215 | 84 | 12 | 124 | 53.4 |
| | CDC Inca | 62.8 | 208 | 94 | 1 | 122 | 30.4 |
| | CDC Meadow* | 65.3 | 191 | 70 | 15 | 130 | 16.3 |
| | CDC Saffron* | 65.0 | 232 | 96 | 0 | 137 | 16.1 |
| | CDC Spectrum | 65.1 | 228 | 101 | 0 | 148 | 21.6 |
| | Delta* | 64.7 | 231 | 100 | 1 | 142 | 17.2 |
| | DL Apollo* | 65.2 | 206 | 102 | 1 | 138 | 25.2 |
| | DS Admiral* | 63.3 | 227 | 97 | 1 | 131 | 20.5 |
| | Durwood | 65.2 | 240 | 95 | 2 | 148 | 21.5 |
| | Hyline* | 63.6 | 227 | 100 | 0 | 123 | 28.8 |
| | Jetset* | 63.7 | 229 | 103 | 1 | 142 | 30.2 |
| | Korando | 64.0 | 264 | 94 | 0 | 157 | 35.6 |
| | LG Amigo* | 63.8 | 219 | 100 | 0 | 133 | 19.9 |
| | LG Sunrise* | 64.6 | 211 | 104 | 0 | 141 | 33.6 |
| | Montech 4152* | 62.8 | 253 | 108 | 0 | 174 | 17.0 |
| | Mystique | 63.6 | 261 | 95 | 0 | 156 | 17.6 |
| | Navarro* | 64.4 | 256 | 101 | 0 | 160 | 18.4 |
| | NDP121587* | 61.4 | 212 | 101 | 1 | 142 | 17.6 |
| | Nette 2010 | 64.8 | 235 | 92 | 3 | 143 | 18.5 |
| | Salamanca | 64.2 | 251 | 96 | 1 | 155 | 20.1 |
| | Spider | 64.9 | 223 | 92 | 2 | 140 | 21.7 |
| | Summit* | 64.3 | 199 | 90 | 6 | 136 | 11.6 |
| | SW Midas | 64.2 | 208 | 81 | 12 | 115 | 25.6 |
| | Treasure | 66.3 | 224 | 88 | 4 | 146 | 25.9 |
| | Unknown | 64.7 | 221 | 97 | 1 | 140 | 23.4 |
| Winter | Austrian Winter | 66.3 | 224 | 88 | 4 | 146 | 25.9 |
| | Vail | 64.7 | 221 | 97 | 1 | 140 | 23.4 |
| Marrowfat | Orka* | 62.6 | 333 | 110 | 1 | 169 | 16.1 |

*Only one sample of cultivar tested

The **cooked firmness** values of peas were slightly lower in the peas from 2019 compared to those of 2016 and 2017, but similar to cooked firmness values observed in 2015 and 2018. The cooked firmness for all peas ranged from 11 to 53 N/g with a mean value of 21 N/g (Table 7). The cooked firmness of peas was different between market classes (Table 8). The green peas had lower firmness values than those of the yellow peas. The value obtained in 2019 did not match any of the cooking firmness values from previous years. The cooked firmness values in yellow peas from 2019 were the same as those in yellow peas from 2015, 2016 and 2018 but lower than values from 2017. Among the green cultivars, Empire had the lowest cooking firmness (12.8 N/g) while Hampton (25.2 N/g) was the firmest (Table 9). In 2018, Hampton also had the highest cooked firmness of the green pea cultivars. CDC Golden had the highest (53.4 N/g) cooking firmness (i.e. most firm) among the yellow cultivars tested while Summit (11.6 N/g) had the lowest cooked firmness (Table 9). The high firmness associated with CDC Golden may be reflective of the sample as many of the individual pea seeds were not fully hydrated after the cooking process. In the soak test, CDC Golden had a high (12%) number of unhydrated seeds, suggesting that this specific sample did not uptake water efficiently.

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 2019 indicated that the peas had L values that were lower than the L values of the peas from previous years (Table 10). This observation was true for both green and yellow peas.

This data indicates that the peas from the 2019 crop year were darker in color than those from previous years. The more negative value for red-green (i.e., "a" value) value in 2019 indicates a greener color than samples from previous 5 years except 2015 (Table 10). The "b" value for green peas from 2019 were significantly lower than peas from previous years except 2014. The lower "b" value indicates a bluer color compared to the peas from 2015 to 2018 crop years. The lower "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 2019 appear greener in color compared to those from previous years. For the yellow pea market class, the 2019 crop had similar lightness values to peas from 2016 but were slightly darker than the peas from the 2013 to 2015 crop years. The "a" value of the yellow peas was on the red side of the scale indicating the lack of a green appearance. The yellow pea in 2019 had "a" values that were similar to "a" values in peas from 2014. The "b" values for yellow peas from 2019 were most similar to "b" values of peas from 2014 crop year. However, the yellowness of peas from 2019 was less than that of peas from 2015 to 2018, but slightly yellower than peas from 2014. The higher "b" values combined with the "a" value on the red part of the scale indicates that the samples would be a light yellow in color. The lower "a" combined with a lower "b" values indicates that the pulses would be a darker yellow color. Therefore, the yellow peas in 2019 appeared dark yellow compared to peas from 2015-2018. However, the peas from 2019 would be similar in appearance to the peas from 2015 (Table 10).

**Table 10. Color quality of dry pea grown in the USA before and after soaking in water 16 hours, 2014-2019.**

| Color Scale* | Mean (SD) of green pea | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Before Soaking | | | | | | After Soaking | | | | | |
| | 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2019 | 2018 | 2017 | 2016 | 2015 | 2014 |
| L (lightness) | 48.99 (3.35) | 51.68 (3.57) | 52.69 (2.82) | 52.01 (2.47) | 62.32 (4.11) | 61.99 (2.19) | 50.42 (4.09) | 45.49 (2.42) | 47.52 (3.22) | 46.86 (2.68) | 57.83 (4.27) | 55.12 (2.58) |
| a (red-green) | -2.46 (0.92) | -1.92 (0.77) | -1.24 (1.15) | -0.98 0.86 | -3.53 (1.48) | -2.10 (0.89) | -6.28 (1.20) | -6.16 (0.77) | -5.24 (1.91) | -5.14 (1.18) | -9.07 (3.87) | -7.95 (2.56) |
| b (yellow-blue) | 9.23 (0.92) | 14.15 (1.49) | 15.11 (1.51) | 14.01 (1.26) | 15.31 (1.52) | 8.79 (0.84) | 12.63 (2.25) | 28.52 (2.65) | 28.63 (2.74) | 27.39 (1.82) | 22.57 (6.28) | 18.73 (2.56) |
| Color Difference | 6.44 (3.05) | 16.45 (2.53) | 15.39 (2.64) | 15.17 (2.02) | 11.44 (5.34) | 13.43 (1.15) | | | | | | |
| **Color Scale** | **Mean (SD) of yellow pea** | | | | | | | | | | | |
| | **Before Soaking** | | | | | | **After Soaking** | | | | | |
| | **2019** | **2018** | **2017** | **2016** | **2015** | **2014** | **2019** | **2018** | **2017** | **2016** | **2015** | **2014** |
| L (lightness) | 56.69 (2.98) | 58.76 (2.39) | 58.73 (1.70) | 57.29 (2.52) | 71.33 (1.87) | 65.83 (0.98) | 60.74 (2.03) | 59.96 (1.98) | 60.56 (2.19) | 69.51 (1.71) | 68.00 (3.78) | 64.76 (1.47) |
| a (red-green) | 4.97 (0.71) | 6.91 (0.99) | 6.83 (1.34) | 7.16 (0.84) | 6.51 (0.79) | 4.64 (0.43) | 3.89 (1.20) | 9.38 (0.98) | 9.60 (2.38) | 9.62 (0.90) | 4.65 (1.73) | 4.57 (0.33) |
| b (yellow-blue) | 14.48 (1.75) | 19.21 (1.53) | 20.40 (1.92) | 19.35 (1.37) | 21.99 (2.23) | 13.51 (1.20) | 21.15 (3.19) | 37.67 (2.65) | 38.25 (4.44) | 36.70 (2.55) | 27.56 (5.19) | 26.50 (3.36) |
| Color Difference | 8.46 (2.52) | 19.10 (2.95) | 18.67 (3.64) | 19.96 (2.52) | 8.41 (5.24) | 13.04 (2.37) | | | | | | |

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

The color of the dry peas changed after the soaking process. The change in color was less for green peas from the 2019 crop year compared to the previous crop years (Table 10). The green peas became lighter (higher L) while the "a" value became more negative (i.e., greener), but more yellow (i.e., increased b value). This trend was opposite of previous crop years. The lower initial L value may be a reason for the increasing L values during soaking. In 2019, lightness increased after soaking of the yellow peas, but to a greater extent compared to 2017 and 2018 pea samples. In addition, soaking increased the greenness (i.e. lower "a" values) and increased yellowness (i.e. higher "b" values) of the yellow peas. This suggests that the peas appeared light yellow after soaking. 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 10).

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 2019 were less than those previously reported for green peas. Greater color difference was observed in yellow pea samples from 2014 and 2016 – 2018 than color differences in yellow peas from 2019. The 2015 yellow pea samples had similar color difference score as those of 2019. The Banner and PRO 131-7123 cultivars from 2019 had the lowest L values (Table 11). Columbian had the most negative "a" value and one of the highest "b" values. Majoret had the highest L value. Mixed results were observed in 2019 regarding the L value after soaking. In some samples the L value increased while in others a decreased L value was observed. The pea samples "a" value became more negative (i.e., greener) and yellow (i.e. increased "b" value).

The greatest color difference was observed in the Arcadia cultivar while PRO 131-7123 underwent the least color change. The cultivars of the yellow peas had L values between 53.88 and 60.82, with CDC Golden being the darkest and DS Admiral being the lightest (Table 11). Treasure retained the darkest color after soaking while Bridger became the lightest. Mystique had the highest redness ("a" value) score while the lowest was observed for the Montech 4152 (Table 11). After soaking, CDC Golden and Bridger had the lowest and highest redness scores, respectively. The yellowness of the dry yellow pea was greatest for CDC Inca and lowest for Montech 4152. After soaking, LG Sunrise had the highest yellowness values while Treasure had the lowest. The greatest color difference was observed in the LG Sunrise cultivar. The increase in lightness and yellowness during soaking likely contributed to the greatest color difference. CDC Saffron and Delta had the least color change during soaking.

The Austrian Winter peas had the lowest L and "b" values of all pea samples evaluated, both pre-soak and post-soak. The Vail winter pea was darker than green peas but lighter than the Austrian Winter. However, the lightness value of both winter peas was similar after soaking. The significant change in lightness of the Austrian Winter pea like was the reason for the high color change value (Table 11). Marrowfat pea sample had the highest L value of all peas. This pea sample had a very light green to white appearance. However, after soaking the sample appeared green and is likely the reason for the high (12.6) color difference value.



**Table 11. Color quality of USA dry pea cultivars before and after soaking, 2019.**

| Market Class | Cultivar | Mean Color Values* | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Before Soaking | | | After Soaking | | | Color |
| | | L | a | b | L | a | b | Difference |
| Green | AAC Comfort** | 52.70 | -2.80 | 9.38 | 48.59 | -6.42 | 11.13 | 5.75 |
| | Aragorn** | 51.35 | -3.44 | 9.04 | 47.03 | -6.64 | 10.30 | 5.52 |
| | Arcadia | 50.05 | -2.32 | 8.81 | 54.05 | -6.68 | 13.96 | 8.66 |
| | Ariel** | 49.80 | -3.19 | 8.90 | 47.14 | -7.26 | 11.34 | 5.45 |
| | Banner | 44.28 | -3.22 | 9.28 | 45.86 | -6.37 | 10.65 | 3.96 |
| | CDC Greenwater | 52.15 | -1.60 | 8.70 | 51.27 | -6.11 | 13.70 | 8.37 |
| | Columbian** | 47.63 | -3.72 | 10.14 | 47.17 | -7.07 | 11.14 | 3.65 |
| | Empire** | 51.98 | -1.33 | 8.10 | 50.57 | -5.06 | 11.76 | 5.41 |
| | Ginny | 50.09 | -2.87 | 10.09 | 47.97 | -7.00 | 12.87 | 6.56 |
| | Greenwood | 46.40 | -2.65 | 9.09 | 47.96 | -6.37 | 11.80 | 5.01 |
| | Hampton | 48.47 | -2.99 | 10.31 | 48.66 | -6.05 | 11.26 | 3.52 |
| | Majoret | 52.83 | -1.76 | 8.97 | 52.21 | -5.65 | 12.83 | 5.87 |
| | Pro 131-7123 | 44.33 | -3.35 | 9.19 | 45.05 | -6.32 | 9.69 | 3.38 |
| | Shamrock | 49.34 | -1.18 | 10.66 | 52.75 | -4.00 | 14.49 | 6.12 |
| Yellow | AAC Carver | 56.45 | 4.73 | 14.07 | 60.47 | 3.89 | 20.79 | 8.16 |
| | AAC Chrome** | 56.83 | 4.73 | 12.90 | 60.51 | 4.07 | 20.00 | 8.03 |
| | AAC Profit | 57.88 | 5.84 | 15.59 | 61.72 | 4.29 | 22.52 | 8.34 |
| | AC Agassiz | 58.44 | 4.99 | 14.63 | 62.16 | 3.96 | 20.83 | 7.95 |
| | AC Earlystar | 57.68 | 4.63 | 14.42 | 63.98 | 3.53 | 24.35 | 12.01 |
| | Bridger** | 59.08 | 5.73 | 14.03 | 64.04 | 5.84 | 28.36 | 15.16 |
| | CDC Amarillo | 57.21 | 5.06 | 14.20 | 61.09 | 4.24 | 23.18 | 10.21 |
| | CDC Golden** | 53.88 | 4.63 | 13.55 | 60.42 | 3.38 | 19.38 | 8.88 |
| | CDC Inca | 59.32 | 4.99 | 17.04 | 58.69 | 4.35 | 23.70 | 7.55 |
| | CDC Meadow** | 54.10 | 4.89 | 13.72 | 59.75 | 4.10 | 20.54 | 8.89 |
| | CDC Saffron** | 59.50 | 4.81 | 14.04 | 60.44 | 3.39 | 19.57 | 5.84 |
| | CDC Spectrum | 60.45 | 5.16 | 16.11 | 60.86 | 4.63 | 23.81 | 8.01 |
| | Delta** | 60.57 | 5.07 | 14.87 | 61.31 | 4.10 | 20.49 | 5.84 |
| | DL Apollo** | 58.49 | 4.15 | 15.54 | 62.67 | 4.07 | 27.77 | 13.04 |
| | DS Admiral** | 60.82 | 5.26 | 14.04 | 65.08 | 5.05 | 27.75 | 14.36 |
| | Durwood | 56.28 | 4.34 | 13.73 | 60.25 | 3.47 | 20.73 | 8.25 |
| | Hyline** | 58.00 | 4.18 | 14.86 | 61.84 | 4.07 | 26.57 | 12.45 |
| | Jetset** | 59.04 | 4.43 | 14.72 | 62.92 | 4.21 | 28.36 | 14.22 |
| | Korando | 59.57 | 4.73 | 14.46 | 62.64 | 4.78 | 23.90 | 10.10 |
| | LG Amigo** | 57.75 | 5.53 | 13.86 | 61.47 | 4.79 | 20.37 | 7.56 |
| | LG Sunrise** | 57.22 | 4.49 | 14.19 | 62.71 | 4.90 | 28.87 | 15.69 |
| | Montech 4152** | 54.34 | 4.13 | 12.02 | 60.38 | 3.49 | 18.60 | 8.97 |
| | Mystique | 60.56 | 5.88 | 16.33 | 62.54 | 5.05 | 21.73 | 5.93 |
| | Navarro** | 59.53 | 4.91 | 13.75 | 60.66 | 4.23 | 20.33 | 6.72 |
| | NDP121587** | 55.04 | 5.14 | 13.34 | 59.46 | 4.24 | 20.09 | 8.12 |
| | Nette 2010 | 54.94 | 4.83 | 14.69 | 60.14 | 3.63 | 20.50 | 8.06 |
| | Salamanca | 56.16 | 5.16 | 14.13 | 60.18 | 4.11 | 19.84 | 7.53 |
| | Spider | 55.98 | 4.48 | 13.84 | 61.11 | 3.60 | 21.30 | 9.25 |
| | Summit** | 54.26 | 4.55 | 14.04 | 59.88 | 3.89 | 20.18 | 8.37 |
| | SW Midas | 53.64 | 4.67 | 14.48 | 58.97 | 3.57 | 19.24 | 7.42 |
| | Treasure | 55.14 | 5.18 | 14.89 | 58.35 | 1.38 | 18.00 | 8.06 |
| | Unknown | 56.12 | 5.35 | 14.05 | 60.15 | 4.45 | 20.56 | 8.04 |
| Winter | Austrian Winter | 31.37 | 0.49 | 5.91 | 42.39 | 1.09 | 10.25 | 12.43 |
| | Vail | 42.04 | -3.35 | 8.67 | 46.06 | -6.44 | 10.53 | 5.44 |
| Marrowfat | Orka** | 65.45 | 1.80 | 15.81 | 54.40 | -1.21 | 20.93 | 12.55 |

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

# Pasting Properties

The peas from 2019 had peak, and hot paste viscosities that were most similar to peas from 2016 and were similar to the 5-year average, but higher than the values of peas from 2017 and 2018 (Table 12). In contrast, cold paste viscosity of the peas from 2019 were similar to the cold paste viscosity for peas harvested in 2017 and 2018. Mean peak time was slightly less than the 5-year mean value, but comparable to values from 2015 through 2018. Pasting temperature ranged from 72 to 80 °C, with a mean of 76.4°C. The mean value is comparable to peas from previous years. The pasting characteristics were similar between the green and yellow pea market classes, although yellow peas tended to have slightly higher values. Pea flour peak viscosities of 143 and 148 RVU were recorded for the green and yellow market classes, respectively (Table 13). Green peas from 2019 had higher peak viscosities than the peas harvested in 2015, 2017 and 2018. Hot paste viscosity of green peas from 2019 were less than values in peas from 2014 and 2016, but comparable to peas harvested in 2017 and 2018. In contrast, the mean cold paste viscosity of green pea from 2019 was lower than other harvest years except 2015. The pasting characteristics of the yellow peas were most comparable to peas from 2016 (Table 13). With the exception of cold paste viscosity, viscosity values for peas from 2019 were higher than the values for peas from other harvest years except 2016. Within each market class, variability in starch characteristics was observed among cultivars. In the green market class, the Aragorn cultivar had the highest peak, hot paste and cold paste viscosities (Table 14). In contrast, Hampton had the lowest peak, and hot paste viscosities while Columbian had the lowest cold paste viscosity. Hampton in 2018 also had the lowest peak and hot paste viscosities among the green peas. The breakdown of starch during heating was greatest in Aragorn and Ariel and least in Majoret. LG Sunrise had the highest peak viscosity among yellow cultivars while AAC Chrome and DL Apollo had the greatest hot and cold paste viscosities, respectively.

The lowest peak and hot paste viscosities of the peas in the yellow market class were observed in the NDP121587 sample (Table 14). The lowest cold paste viscosity was observed in the CDC Amarillo cultivar. The breakdown of the paste during heating was greatest in LG Sunrise and least for CDC Saffron cultivars. The type C pasting profile was demonstrated by all of the cultivars tested. This curve is represented by a minimally definable pasting peak, a small breakdown in viscosity and high final peak viscosity. The breakdown ranged from 2 to 26 RVU, which represents little breakdown of the starch paste.

# Lentil Quality

## Sample Distribution

A total of 43 lentil samples were collected from Idaho, Montana, North Dakota and Washington between August and November 2019. Growing location, number of samples, market class, and genotype details of these lentil samples can be found in Table 15. Pardina represented all 15 of the Spanish brown lentils while 6 of the 22 green lentils were the Brewer cultivar. Redchief (4) was the most common red lentil evaluated in the survey.

**Table 15. Description of lentils used in the 2019 pulse quality survey.**

| State | No. of Samples | Market Class | Cultivars |
|---|---|---|---|
| Idaho | 17 | Green | Brewer |
| | | | Merrit |
| | | Red | Redchief |
| | | Spanish Brown | Pardina |
| Montana | 18 | Green | Avondale |
| | | | CDC Impress |
| | | | CDC Imvincible |
| | | | CDC Richlea |
| | | | CDC Viceroy |
| | | | Eston |
| | | | Merrit |
| | | | Sage |
| | | Red | CDC Maxim |
| | | Spanish Brown | Pardina |
| North Dakota | 1 | Green | NDSU Eagle |
| Washington | 7 | Green | Brewer |
| | | | Merrit |
| | | Spanish Brown | Pardina |

## Proximate Composition of Lentils

### Moisture

The moisture content of lentils ranged from 7.7 to 15.1% in 2019 (Table 16). The mean moisture content (9.8%) was slightly higher than the 5-year mean of 9.4% and was most similar to the mean value of lentils from 2015, but lower than lentils from 2014. Overall, all samples evaluated had moisture contents below the 13-14% recommended general storability. The moisture contents of the different market classes were between 8.8 and 10.3% (Table 17). The green lentils had a mean moisture content of 10.3% while red and Spanish brown lentils had moisture contents of 8.8 and 9.8%, respectively. The green lentils from 2019 had higher moisture contents than the five previous years except 2014 and was 0.8 percentage points higher than the 5-year mean moisture content. The 2019 red lentils had lower moisture contents than lentils from the previous five years except for lentils from 2017 and 2018. The 5-year mean moisture content was 0.3 percentage unit higher than the lentils from 2019. Spanish brown lentils had a mean moisture content that was comparable to lentil from 2014, but higher than lentils from 2015 through 2018. The highest moisture contents were observed in the CDC Richlea (13.0%) and NDSU Eagle (11.2%) cultivars (i.e., green lentils) while CDC Maxim (10.5%) cultivar in the red market class had the highest moisture content (Table 18). However, all lentils remained under the maximum moisture of 14%, which is necessary for storing pulses.

### Ash

Ash content of lentils ranged from 2.0 to 3.1% with a mean of 2.4% (Table 16). The mean ash content of lentils grown in 2019 was approximately the same as the 5-year mean of 2.6%. Ash content is a general indicator of minerals present. Furthermore, the ash contents remain relatively constant over the last 5 years. The mean ash contents of the different market classes were all 2.4% (Table 17). The Brewer, CDC Viceroy, Merrit and NDSU Eagle cultivar had the highest (2.5%) mean ash content of the green lentils. CDC Redchief (red) and Pardina (Spanish brown) cultivars also had mean ash contents of 2.5% (Table 18). However, one samples of Pardina did have an ash content of 3.1%, which was the highest among all lentil samples. The lowest (2.0%) ash content was observed in the Sage (green) cultivar.



### Fat

Fat content of lentils ranged from 0.6 to 2.2% with a mean of 1.1% (Table 16). The fat content was measured in 2017 for the first time; thus, no 5-year mean value is available. However, lentils from the 2017 (2.1%) and 2018 (2.6%) harvest years were both higher than the mean fat contents from 2019. Literature reports indicate that lentils have fat contents between 1 and 3%; therefore, the fat content of most of the lentils grown in 2019 fall at the lower end of the range reported by others. No difference in fat percentages were observed between the market classes (Table 17). Brewer (green) cultivar had the highest mean (1.3%) fat content while Sage (Green) had the lowest (0.6%) fat content among cultivars (Table 18).

### Protein

Protein content of lentils averaged 24.3% in 2019 (Table 16). The protein content ranged from 20.8 to 27.6%. The mean protein content of lentils grown in 2019 was higher than lentils grown in 2014-2017 (i.e. 22-24%) and the 5-year mean value of 23.3%. The protein contents of the three market classes were different (Table 17). Green and Red lentils had the highest mean protein content (24.8 and 24.7%, respectively) among lentil market classes while Spanish brown lentils had mean protein values of 23.5%. The CDC Imvincible (green) and CDC Richlea (green) cultivars had the highest and lowest protein percentage, respectively, among known cultivars (Table 18).

### Total Starch

Total starch content of lentils ranged from 39.1 to 46.9%, with a mean of 42.8% (Table 16). The mean total starch percentage of lentils grown in 2019 was lower than starch percentage in lentils from the previous five years except 2015, but was similar to the 5-year mean of 42.7%.

The starch contents of the lentils in the green and red market classes were 42.1 and 42.8%, respectively while lentils in the Spanish brown market class had a mean starch content of 43.9% (Table 17). The mean starch percentage for lentil from 2019 was the same as those from 2018. However, some variation in starch content was observed in red lentils from harvest years 2014-2017. Lentils from the green market class in 2019 tended to have lower percent starch than lentils from other harvest years except the 2015 crop years (Table 17). The Spanish brown lentils had total starch percentages that were higher than lentils from previous harvest years except 2018.The starch percentage in Spanish brown lentils was 2% points higher than the 5-year mean starch value. The highest mean starch content was observed in Sage (green) cultivar at 45% (Table 18). However, one of the Pardina samples had a percent starch value of 46.9%. The Brewer and CDC viceroy cultivars had the lowest (41.3%) mean starch content among known cultivars tested (Table 17).

**Table 16. Proximate composition of lentils grown in the USA, 2014-2019.**

| Proximate Composition (%) | 2019 | | Mean 2018 | Mean 2017 | Mean 2016 | Mean 2015 | Mean 2014 | 5-year |
|---|---|---|---|---|---|---|---|---|
| | Range | Mean (SD) | Mean (SD) | Mean (SD) | Mean (SD) | Mean (SD) | Mean (SD) | Mean (SD) |
| Moisture | 7.7-15.1 | 9.8 (1.6) | 8.4 (1.1) | 8.8 (1.0) | 9.0 (1.0) | 9.7 (1.0) | 10.5 (1.1) | 9.4 (1.1) |
| Ash | 2.0-3.1 | 2.4 (0.3) | 2.6 (0.3) | 2.5 (0.2) | 2.5 (0.2) | 2.7 (0.3) | 2.5 (0.4) | 2.6 (0.1) |
| Fat | 0.6-2.2 | 1.1 (0.3) | 2.6 (0.8) | 2.1 (0.5) | * | * | * | nd |
| Protein | 20.8-27.6 | 24.3 (1.5) | 24.4 (1.9) | 23.5 (1.7) | 21.7 (1.6) | 22.6 (1.2) | 23.6 (1.5) | 23.3 (1.0) |
| Total Starch | 39.1-46.9 | 42.8 (1.6) | 44.0 (2.9) | 44.0 (2.0) | 43.3 (3.1) | 38.3 (2.7) | 43.5 (3.2) | 42.7 (2.6) |

*= not reported; nd = not determined

Table 17. Proximate composition of different market classes of lentils grown in the USA, 2014-2019.

| Market Class | Proximate Composition (%) | Mean (SD) 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 5-Year Mean (SD) |
|---|---|---|---|---|---|---|---|---|
| Green | Moisture | 10.3 (1.8) | 8.8 (1.1) | 9.0 (0.8) | 9.2 (0.9) | 9.8 (1) | 10.9 (1.2) | 9.5 (0.8) |
| | Ash | 2.4 (0.2) | 2.6 (0.4) | 2.4 (0.2) | 2.5 (0.2) | 2.9 (0.2) | 2.4 (0.1) | 2.6 (0.2) |
| | Fat | 1.1 (0.4) | 2.8 (0.8) | 2.1 (0.5) | * | * | * | nd |
| | Protein | 24.8 (1.5) | 24.2 (2.0) | 23.2 (1.7) | 21.4 (1.5) | 22.5 (1) | 23.2 (1.5) | 22.9 (1.0) |
| | Total Starch | 42.1 (1.4) | 44.1 (3.4) | 44.0 (2.1) | 43.3 (3.2) | 38.5 (2) | 44.6 (3.5) | 42.9 (2.5) |
| Red | Moisture | 8.8 (1.0) | 7.6 (1.1) | 8.6 (1.2) | 9.3 (0.8) | 10.4 (1) | 10.0 (0.8) | 9.1 (1.1) |
| | Ash | 2.4 (0.3) | 2.8 (0.1) | 2.5 (0.2) | 2.6 (0.2) | 2.7 (0.4) | 2.9 (0.6) | 2.7 (0.2) |
| | Fat | 1.2 (0.3) | 2.1 (0.3) | 2.0 (0.5) | * | * | * | nd |
| | Protein | 24.7 (0.8) | 26.0 (0.6) | 24.3 (1.5) | 23.3 (1.2) | 22.8 (2) | 24.2 (1.3) | 24.1 (1.2) |
| | Total Starch | 42.8 (0.7) | 42.8 (1.2) | 43.9 (2.0) | 44.9 (1.8) | 39.1 (2) | 41.2 (0.6) | 42.4 (2.3) |
| Spanish Brown | Moisture | 9.8 (1.2) | 7.8 (0.8) | 8.2 (0.7) | 7.8 (0.7) | 8.9 (1) | 9.7 | 8.5 (0.8) |
| | Ash | 2.4 (0.3) | 2.6 (0.2) | 2.7 (0.2) | 2.5 (0.3) | 2.9 (0.2) | 2.2 | 2.6 (0.3) |
| | Fat | 1.1 (0.2) | 2.0 (0.5) | 2.2 (0.5) | * | * | * | nd |
| | Protein | 23.5 (1.2) | 24.3 (1.4) | 23.6 (1.2) | 20.7 (1.0) | 22.8 (1) | 22.2 | 22.7 (1.4) |
| | Total Starch | 43.9 (1.5) | 44.4 (1.2) | 43.9 (1.7) | 41.1 (2.8) | 36.8 (4) | 42.5 | 41.7 (3.0) |

*= not reported; nd = not determined

# Physical Parameters of Lentils

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 2019 and comparisons to the 5-year mean values when applicable.

**Test weight** ranged from 57-66 lbs/ bu with a mean of 62.4 lbs/bu. This mean value was slightly higher than the 5-year mean of 62 lbs/bu (Table 19). The test weight for all lentil samples harvested in 2019 was comparable to lentils harvested in previous years. The mean test weight of lentils in the Red market class was 2 to 3 percentage points higher than test weights of lentils from the Spanish brown and green market classes (Table 20). Maximum test weight of 65.9 lbs/bu was observed in one sample of the CDC Viceroy cultivar. This same cultivar also had the highest test weight if the 2018 samples. However, the mean test weight for this cultivar was 63.7 lbs/bu. The Eston and Sage (green) and Pardina (Spanish brown) cultivars had the next highest values at approximately 64% (Table 21). The lowest mean test weight (59 lbs/bu) was found in the Brewer and CDC Maxim cultivars.

The range and mean **1000 seed weight** of lentils grown in 2019 were 28 to 65 g and 42.8 g, respectively (Table 19). The mean value was lower than the 5-year mean of 44 g. Lentils of the red market class had a mean 1000 seed weight of 37 g, which was lower than the 5-yr mean for red lentils. However, the mean 1000 seed weight for 2019 red lentils was most closely matched the 1000 seed weight of red lentils from the 2015 through 2017 crop years. In contrast, lentils of the green market class had a mean 1000 seed weight of 46 g, which is higher than the 5-year mean value (Table 20). However, green lentils from 2015 through 2018 had higher mean 1000 seed weights compared to the 2019 data. Lentils in the Spanish brown market class had mean 1000 seed weight that was higher than previous years. CDC Imvincible had the lowest 1000 seed weight at 28 g, followed by CDC Viceroy (31 g). Brewer had the highest 1000 seed weight at 59 g (Table 21).



Table 18. Mean proximate composition of lentil cultivars grown in the USA in 2019.

| Market Class | Cultivar | Concentration (%) Moisture | Ash | Fat | Protein | Starch |
|---|---|---|---|---|---|---|
| Green | Avondale | 11.6 | 2.3 | 0.9 | 22.8 | 43.5 |
| | Brewer | 8.3 | 2.5 | 1.3 | 25.5 | 41.3 |
| | CDC Impress* | 10.7 | 2.4 | 0.9 | 25.0 | 42.6 |
| | CDC Imvincible* | 10.3 | 2.1 | 0.8 | 26.8 | 41.6 |
| | CDC Richlea* | 13.0 | 2.3 | 0.8 | 23.1 | 42.9 |
| | CDC Viceroy | 10.8 | 2.5 | 1.2 | 25.5 | 41.3 |
| | Eston* | 10.1 | 2.1 | 0.7 | 25.4 | 42.8 |
| | Merrit | 9.9 | 2.5 | 1.2 | 24.7 | 41.5 |
| | NDSU Eagle* | 11.2 | 2.5 | 0.9 | 24.3 | 42.0 |
| | Sage* | 10.8 | 2.0 | 0.6 | 23.2 | 45.0 |
| Red | CDC Maxim* | 10.5 | 2.1 | 0.8 | 25.3 | 43.0 |
| | Red Chief | 8.4 | 2.5 | 1.4 | 24.6 | 42.7 |
| Spanish Brown | Pardina | 9.2 | 2.5 | 1.1 | 23.5 | 43.9 |

*Only one sample of cultivar tested

**Water hydration capacity** of lentils ranged from 74 to 105%, with a mean of 91% (Table 19). The 2019 mean water hydration capacity value was similar to lentils from 2016, but lower in lentils from other harvest years. The water hydration capacity (84%) was lowest for red lentils while the green (93%) and Spanish brown (91%) market classes had similar water hydration capacities (Table 20). The water hydration capacities of all lentils from 2019 were lower than the 5-year mean values from their respective classes. Green lentils had comparable water hydration capacity to green lentils grown in 2014 and 2016. The red market class had a 2019 mean water hydration value that most closely match the lentils from 2016. The Spanish brown market classes had mean water hydration capacities that were lower than lentils from 2015 and 2017, but comparable to lentils grown in 2014 and 2018. The mean water hydration capacity ranged from 83% in NDSU Eagle (green) to 103% in Red Chief (red). Most other cultivars had water hydration capacities of approximately 91% (Table 21).

Table 19. Physical parameters of lentils grown in the USA, 2014-2019.

| Physical Parameters | 2019 Range | 2019 Mean (SD) | 2018 Mean | 2017 Mean | 2016 Mean | 2015 Mean | 2014 Mean | 5-year Mean (SD) |
|---|---|---|---|---|---|---|---|---|
| Test Weight (lb/Bu) | 57.10-65.95 | 62.4 (2.5) | 62.9 (2.2) | 62 (2) | 62 (3) | 62 (2) | 61 (4) | 62 (1) |
| 1000 Seed Wt (g) | 28.4-65.4 | 42.8 (10.8) | 42 (9) | 44 (9) | 45 (9) | 43 (9) | 44 (12) | 44 (1) |
| Water Hydration Capacity (%) | 74-105 | 91 (8) | 99 (2) | 101 (3) | 91 (11) | 118 (7) | 94 (4) | 101 (11) |
| Unhydrated Seeds (%) | 0-16 | 4 (4) | 2 (3) | 1 (2) | 4 (7) | 1 (1) | 2 (1) | 2 (1) |
| Swelling Capacity (%) | 106-181 | 143 (15) | 140 (15) | 144 (28) | 140 (28) | 161 (33) | 102 (17) | 137 (22) |
| Cooked Firmness (N/g) | 9.4-28.3 | 15.8 (4.8) | 15 (3) | 14.9 (3.9) | 13.4 (2.5) | 11.9 (2) | * | nd |

*data not reported, nd = not determined

**Table 20. Physical parameters of different market classes of lentils grown in the USA, 2014-2019.**

| Market class | Physical Parameter | 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 5-Year Mean |
|---|---|---|---|---|---|---|---|---|
| Green | Test Weight (lb/Bu) | 61.8 (2.4) | 62.2 (1.8) | 61 (2) | 62 (2) | 62 (2) | 63 (3) | 62 (1) |
| | 1000 Seed Wt (g) | 46 (12) | 47 (8) | 48 (8) | 49 (8) | 47 (9) | 32 (5) | 45 (7) |
| | Water Hydration Capacity (% | 93 (6) | 100 (9) | 103 (10) | 95 (9) | 121 (18) | 94 (4) | 103 (11) |
| | Unhydrated Seeds (%) | 2 (2) | 1 (1) | 1 (1) | 2 (4) | 1 (1) | 3.0 (1) | 2 (1) |
| | Swelling Capacity (%) | 145 (11) | 140 (15) | 144 (18) | 148 (26) | 148 (32) | 103 (9) | 128 (23) |
| | Cooked Firmness (N/g) | 15.5 (5.3) | 14.5 (3.8) | 15.1 (4.4) | 13.5 (2.8) | 12.5 (2.0) | * | nd |
| Red | Test Weight (lb/Bu) | 64.2 (0.4) | 61.6 (2.1) | 63 (3) | 63 (4) | 64 (1) | 60 (3) | 62 (2) |
| | 1000 Seed Wt (g) | 36.8 (6) | 41 (5) | 36 (6) | 36 (3) | 36 (2) | 50 (9) | 40 (6) |
| | Water Hydration Capacity (% | 84 (8) | 106 (12) | 95 (16) | 87 (3) | 98 (9) | 95 (2) | 96 (7) |
| | Unhydrated Seeds (%) | 8 (1) | 1 (1) | 2 (2) | 4 (3) | 2 (1) | 2.0 (1) | 2 (1) |
| | Swelling Capacity (%) | 140 (5) | 143 (15) | 132 (11) | 125 (21) | 155 (15) | 105 (10 | 132 (19) |
| | Cooked Firmness (N/g) | 14.8 (5.7) | 15.2 (3.5) | 14.9 (2.2) | 13.2 (2.1) | 12.0 (1.0) | * | nd |
| Spanish Brown | Test Weight (lb/Bu) | 62.4 (2.0) | 65.4 (0.6) | 64 (2) | 66 (1) | 64 (2) | 66 | 65 (1) |
| | 1000 Seed Wt (g) | 43 (7) | 32 (2) | 40 (10) | 36 (2) | 38 (8) | 36 | 36 (3) |
| | Water Hydration Capacity (% | 91 (8) | 93 (10) | 102 (15) | 79 (16) | 124 (6) | 91 | 98 (17) |
| | Unhydrated Seeds (%) | 3.9 (6) | 6 (3) | 3 (4) | 13 (13) | 1 (1) | 2 | 5 (5) |
| | Swelling Capacity (%) | 143 (21) | 137 (16) | 144 (18) | 118 (26) | 191 (23) | 115 | 141 (31) |
| | Cooked Firmness (N/g) | 15.8 (2.8) | 15.5 (1.8) | 13.6 (3.3) | 13.1 (0.8) | 10.8 (1.3) | * | nd |

*data not reported; nd = not determined

**Table 21. Mean physical parameters of USA lentil cultivars grown in 2019.**

| Market Class | Cultivar | Test Weight (lb/bu) | 1000 Seed Wt (g) | Water Hydration Capacity (%) | Unhydrated Seeds (%) | Swelling Capacity (%) | Cooked Firmness (N/g) |
|---|---|---|---|---|---|---|---|
| Green | Avondale | 62.4 | 48 | 94 | 1 | 147 | 15.8 |
| | Brewer | 59.2 | 59 | 97 | 4 | 138 | 21.1 |
| | CDC Impress* | 61.4 | 47 | 101 | 0 | 148 | 17.7 |
| | CDC Imvincible* | 64.4 | 28 | 91 | 4 | 135 | 9.5 |
| | CDC Richlea* | 62.1 | 50 | 91 | 1 | 147 | 12.7 |
| | CDC Viceroy | 63.7 | 31 | 86 | 1 | 153 | 10.6 |
| | Eston* | 64.5 | 34 | 91 | 3 | 135 | 11.5 |
| | Merrit | 60.2 | 58 | 98 | 0 | 148 | 20.4 |
| | NDSU Eagle* | 60.4 | 38 | 83 | 1 | 138 | 10.0 |
| | Sage* | 64.3 | 35 | 91 | 6 | 139 | 13.7 |
| Red | CDC Maxim* | 59.1 | 38 | 88 | 2 | 141 | 15.6 |
| | Red Chief | 59.9 | 50 | 103 | 1 | 142 | 21.3 |
| Spanish Brown | Pardina | 64.2 | 37 | 84 | 8 | 140 | 14.8 |

*Only one sample of cultivar tested



Unhydrated seed percentage ranged from 0 to 16% with a mean of 4%, which is more than the 5-year mean of 2% (Table 19). The mean unhydrated seed percentage was higher due to the presence of seven samples with unhydrated seed levels of greater than 10%. The amount of unhydrated seeds in all market classes varied from 1 to 8% (Table 20). The green and Spanish brown lentils had lower unhydrated seed values compared to the five-year mean values. The unhydrated seed count in the red lentils was significantly higher than unhydrated seed amounts in lentils from other harvest years. Several cultivars had no or one unhydrated seed percentage while Pardina cultivar had the highest at 8% (Table 21). The Sage cultivar also had a high unhydrated seed percentage (6%). In 2018, Pardina also had the highest unhydrated seed percentage at 6%.

The swelling capacity of all lentils ranged from 106 to 81%, with a mean value of 143% (Table 19). The mean swelling capacity from 2019 samples was greater than that of lentils from the 2014 harvest year and similar to the lentils from 2016, 2017 and 2018, but lower than the swelling capacities of lentils from the 2015 harvest year. The swelling capacity of lentils was similar between market classes with green lentils having a slightly higher swelling capacity (Table 20). Swelling capacities of 145% was observed in the green market class for lentils grown in 2019, which was less than the swelling capacities of green lentils from the 2015 and 2016 harvest years. CDC Viceroy had the greatest swelling capacity (153%) while Easton and CDC Imvincible had the lowest (135%) among green cultivars (Table 21). A swelling capacity of 140% for lentils in the red market class was greater that red lentils from other harvest years except 2015 and 2018. Although Red chief had a higher swelling capacity among the cultivars tested, the water hydration values were essentially the same (Table 21). The Spanish brown Lentils had swelling capacities similar to lentils from 2017.

The cooked firmness of all lentils ranged from 9.4 to 28.3 N/g with a mean value of 15.8 N/g (Table 19). The lentils from 2019 had slightly greater cooked firmness values than lentils from 2018 but significantly greater than lentils from the other harvest years. The cooked firmness of lentils was not significantly different between the green and Spanish brown market classes (Table 20). The 2019 red lentil cooked firmness was comparable to lentils from 2017 and 2018 but firmer than lentils from 2015 and 2016. Among the cultivars, NDSU Eagle (green) had the lowest cooked firmness value while Red Chief (red) and Brewer (green) were the firmest (Table 21).

Color quality was measured using L, a, and b values and from these values a color difference can be determined on lentils before and after soaking (Table 22). Color quality for all lentils in 2019 indicated that the lentils had lower L values than in lentils from previous years. This data indicates that the lentils from the 2019 crop year were darker in color than those from previous years. The lower "a" value (i.e., red-green scale) in the green lentil indicates a less red color while a more negative "a" value for the green lentils indicates a greener color. In 2019, the "a" value of 0.53 indicates that the lentils were greener in 2019 compared to lentils from other harvest years. In the red lentil market class, the 2019 samples were less red based on the lower "a" value compared to red lentils from previous years. The lentils also had a lower "b" value suggesting the samples are less yellow in nature and would have a darker red color compared to sample that had higher "b" values (Table 22). The Spanish brown "a" value was lower in the 2019 samples compared to brown lentils from all other years: therefore, indicating less redness in the sample.

The color of the lentils changed after the soaking process. Green and red market classes became lighter as evidenced by the higher L values (Table 22) compared to pre-soaked lentils. However, the lightness value remained unchanged in the Spanish brown market class after soaking. In the green market class, the decreased "a" value indicated an increase in greenness of the lentils after soaking. In the red lentil market class, "a" increased suggesting more redness was observed in lentil after soaking, this same trend occurred in previous years. The Spanish brown redness value also increased upon soaking of the lentil. Lentils from all market classes became more yellow (i.e., increased b value) after soaking. The color difference in lentil samples was the greatest for the red market class and the least for the Spanish brown market class (Table 22). The color difference value in green lentils was similar to the value observed in 2016. Overall, the colors were less impacted by soaking in comparison to lentils from previous years based on the smaller color difference values compared to lentils from other harvest years.

Among the cultivars, Pardina had the lowest L value followed by CDC Maxim (Table 23). These same two cultivars also had the lowest L values in 2018. The highest L was observed in the Avondale green lentil. This follows expectations that the brown and red lentils would be darker than the green lentils. Except for the Pardina lentils, the L values of lentil increased after soaking with CDC Impress having the highest values (Table 23). The green lentil cultivar became greener (i.e., reduction of the “a” value) after soaking while the red intensity (increased “a” value) of the red and brown cultivars increased during soaking. Sage had the greenest color after soaking while Red Chief had the highest red value. The “b” value increased substantially in all lentils during soaking. The green lentil cultivar CDC Viceroy had the highest “b” value (i.e. yellowness) of the soaked lentils. This is a green coated lentil, but has a yellow cotyledon; thus, the soaking may have reduced the impact of the hull on color and resulted in increased yellowness. The greatest color difference was observed the Red Chief cultivar (Table 23). The increase in redness and yellowness during soaking likely contributed to the greatest color difference in this cultivar. The color of NDSU Eagle was the most stable as this cultivar had the lowest color difference value.

**Table 22. Color quality of lentils grown in the USA before and after soaking, 2014-2019.**

| Color Scale | Mean (SD) of green lentils | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Before Soaking | | | | | | After Soaking | | | | | |
| | 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2019 | 2018 | 2017 | 2016 | 2015 | 2014 |
| L (lightness) | 48.07 (1.91) | 53.97 (3.25) | 56.13 (2.29) | 55.22 (1.19) | 57.14 (5.76) | 63.12 (0.93) | 52.93 (1.52) | 57.69 (1.36) | 57.26 (2.1) | 58.23 (2.01) | 62.29 (1.18) | 59.91 (2.28) |
| a (red-green) | 0.53 (1.43) | 4.34 (1.21) | 5.32 (1.15) | 4.69 (1.42) | 2.49 (2.17) | 2.25 (1.56) | -0.98 (2.86) | 3.86 (1.34) | 4.71 (1.24) | 4.06 (1.42) | 0.59 (1.79) | 0.59 (2.19) |
| b (yellow-blue) | 13.54 (3.45) | 21.28 (1.51) | 22.11 (1.46) | 23.16 (1.38) | 19.55 (5.02) | 15.36 (0.22) | 20.48 (2.35) | 30.73 (2.39) | 31.98 (2.60) | 32.30 (2.60) | 28.30 (1.62) | 25.79 (2.15) |
| Color Difference | 9.31 (3.40) | 10.54 (3.35) | 10.42 (1.85) | 9.82 (1.96) | 6.18 (1.62) | 11.10 | | | | | | |
| Color Scale* | Mean (SD) of red lentils | | | | | | | | | | | |
| | Before Soaking | | | | | | After Soaking | | | | | |
| | 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2019 | 2018 | 2017 | 2016 | 2015 | 2014 |
| L (lightness) | 44.84 (2.08) | 51.13 (4.17) | 46.19 (3.87) | 45.95 (1.70) | 56.84 (5.35) | 56.06 (0.54) | 48.83 (2.48) | 53.01 (3.24) | 48.95 (3.12) | 49.54 (0.75) | 52.51 (0.60) | 51.82 (0.16) |
| a (red-green) | 3.38 (0.60) | 7.38 (0.50) | 7.40 (1.28) | 7.97 (0.63 | 3.71 (1.63) | 4.19 (0.69) | 9.35 (1.84) | 13.63 (1.12) | 12.63 (2.99) | 13.84 (1.08) | 8.64 (0.22) | 7.83 (0.32) |
| b (yellow-blue) | 9.36 (1.49) | 21.28 (1.51) | 13.93 (2.82) | 14.34 (1.34) | 18.58 (4.60) | 7.57 (1.20) | 19.05 (2.52) | 28.44 (2.11) | 28.18 (2.89) | 27.04 (1.85) | 20.29 (1.45) | 21.98 (0.58) |
| Color Difference | 12.12 (1.96) | 13.02 (3.76) | 15.89 (2.89) | 14.51 (2.04) | 6.37 (2.22) | 15.46 | | | | | | |
| Color Scale | Mean (SD) of brown lentils | | | | | | | | | | | |
| | Before Soaking | | | | | | After Soaking | | | | | |
| | 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2019 | 2018 | 2017 | 2016 | 2015 | 2014 |
| L (lightness) | 39.52 (2.39) | 42.71 (6.78) | 44.59 (3.55) | 42.92 (1.12) | 55.71 (5.26) | 54.5 | 39.03 (3.65) | 49.42 (1.75) | 48.84 (3.04) | 47.88 (1.69) | 51.21 (2.82) | 54.3 |
| a (red-green) | 1.72 (0.58) | 5.01 (0.63) | 6.11 (1.02) | 5.21 (0.20) | 3.43 (2.79) | 2.2 | 2.93 (1.25) | 7.08 (0.39) | 7.66 (1.04) | 6.59 (0.45) | 4.66 (0.69) | 0.99 |
| b (yellow-blue) | 6.48 (1.63) | 12.35 (1.57) | 13.18 (2.50) | 12.07 (0.94) | 17.95 (4.79) | 6.65 | 14.69 (1.34) | 29.33 (2.55) | 28.52 (3.85) | 26.59 (1.31) | 19.54 (1.84) | 23.91 |
| Color Difference | 8.72 (1.03) | 19.01 (5.74) | 16.16 (4.43) | 15.56 (1.12) | 5.25 (1.06) | 17.30 | | | | | | |

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

**Table 23. Color quality of USA lentil cultivars before and after soaking, 2019.**

| | | Mean Color Values* | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Before Soaking | | | After Soaking | | | Color |
| Market Class | Cultivar | L | a | b | L | a | b | Difference |
| Green | Avondale | 49.48 | -0.4 | 14.8 | 53.4 | -2.98 | 20.13 | 7.85 |
| | Brewer | 47.45 | 2.6 | 10.5 | 53.0 | 3.30 | 21.23 | 12.25 |
| | CDC Impress** | 48.54 | 0.43 | 12.15 | 54.33 | -1.77 | 20.93 | 10.75 |
| | CDC Imvincible** | 45.67 | -0.39 | 10.85 | 52.41 | -2.67 | 19.68 | 11.34 |
| | CDC Richlea | 47.72 | -0.33 | 15.14 | 53.21 | -2.41 | 19.71 | 7.82 |
| | CDC Viceroy | 48.86 | -0.33 | 16.88 | 52.77 | -2.81 | 21.68 | 7.50 |
| | Eston** | 46.47 | -0.90 | 11.49 | 53.47 | -3.51 | 19.89 | 11.25 |
| | Merrit | 48.62 | 1.93 | 11.66 | 52.37 | 1.09 | 19.86 | 9.25 |
| | NDSU Eagle** | 47.27 | 0.67 | 16.91 | 51.87 | -0.18 | 16.35 | 4.71 |
| | Sage** | 46.14 | -0.91 | 11.10 | 52.82 | -3.75 | 19.93 | 11.43 |
| Red | CDC Maxim** | 41.40 | 2.99 | 6.76 | 44.84 | 6.82 | 14.63 | 9.45 |
| | Red Chief | 45.70 | 3.48 | 10.02 | 49.83 | 9.99 | 20.15 | 12.78 |
| Spanish Brown | Pardina | 39.52 | 1.72 | 6.48 | 39.03 | 2.93 | 14.69 | 8.72 |

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



# Pasting Properties

Peak viscosity, hot and cold paste viscosities and setback values of lentils grown in 2019 were comparable to lentils from 2017 and 2018. Lentils from other harvest years had lower pasting values than lentils from 2019 (Table 24). Mean peak time for lentils in 2019 was less than the 5-year mean value. Pasting temperature ranged from 74 to 81°C, with a mean value of 77.1 °C, which is similar to the pasting temperatures of lentils from 2015. The peak and hot paste viscosities were similar among the green and red market classes (Table 25). However, the peak and hot paste viscosities obtained for lentils in the Spanish brown market class were higher, indicating higher viscosities during the heating phase of the test. In contrast, cold paste viscosities of 242, 249 and 249 RVU were recorded for the green, red and Spanish brown market classes, respectively (Table 25). This suggests that similar final viscosities occurred after a cooling period. Pasting characteristics for all market classes in 2019 were higher than the 5-year mean sample, suggesting that the lentils from 2019 produce thicker pastes and gels. The pasting characteristics of the 2019 lentils from their respective market classes were similar to values from 2016 and 2018 (green), 2016 (red) and 2017 (Spanish brown). Variability in pasting characteristics were observed among cultivars (Table 26). In the green market class, the variability among cultivars was noticeable. Brewer had the lowest peak (133 RVU), hot paste (127 RVU), and cold paste (227 RVU) viscosities among the green lentil cultivars. In contrast, NDSU Eagle had the highest peak (156 RVU) and hot paste (145 RVU) viscosities while Sage had the highest cold paste (289 RVU) viscosity (Table 26). No specific trends in viscosities were observed in the red lentil cultivars in 2019. Overall, similar viscosities of single cultivars grown in 2019 and 2018 were observed. For example, Avondale, Brewer, CDC Richlea and CDC Viceroy had similar peak, hot paste, and cold paste viscosities in 2019 as was observed in the same cultivar grown in 2018. In contrast, 2019 Merrit and NDSU Eagle viscosity data were not similar to the data obtained on these cultivars grown in 2018.

**Table 24. Starch characteristics of lentils grown in the USA, 2014-2019.**

| Starch Characteristic | 2019 Range | 2019 Mean (SD) | 2018 Mean | 2017 Mean | 2016 Mean | 2015 Mean | 2014 Mean | 5-year Mean (SD) |
|---|---|---|---|---|---|---|---|---|
| Peak Viscosity (RVU) | 101-172 | 146 (14) | 142 (18) | 143 (17) | 148 (20) | 124 (17) | 121 (17) | 136 (12) |
| Hot Paste Viscosity (RVU) | 99-158 | 137 (11) | 134 (14) | 136 (15) | 133 (18) | 119 (15) | 115 (13) | 127 (10) |
| Breakdown (RVU) | 1-21 | 9 (6) | 8 (6) | 7 (4) | 15 (6) | 4 (4) | 6 (5) | 8 (4) |
| Cold Paste Viscosity (RVU) | 172-304 | 253 (28) | 245 (29) | 253 (28) | 239 (31) | 205 (25) | 196 (24) | 228 (25) |
| Setback (RVU) | 73-155 | 117 (19) | 111 (16) | 117 (16) | 106 (16) | 86 (13) | 81 (14) | 100 (16) |
| Peak Time (Minute) | 4.68-7.00 | 5.49 (0.52) | 5.85 (0.76) | 5.65 (1) | 5.16 (0.26) | 6 (1) | 6 (1) | 5.73(0.35) |
| Pasting Temperature (°C) | 74.3-80.7 | 77.1 (1.2) | 77.8 (1.8) | 77.8 (2) | 75.9 (1.0) | 77 (3) | 76 (1) | 76.9 (0.9) |

**Table 25. Starch characteristic of different market classes of lentils grown in the USA, 2014-2019.**

| Market class | Physical Parameter | Mean (SD) 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 5-Year Mean (SD) |
|---|---|---|---|---|---|---|---|---|
| Green | Peak Viscosity (RVU) | 142 (13) | 145 (18) | 146 (16) | 149 (22) | 127 (17) | 131 (12) | 140 (10) |
| | Hot Paste Viscosity (RVU) | 133 (8) | 134 (14) | 138 (13) | 132 (20) | 121 (14) | 122 (9) | 129(10) |
| | Breakdown (RVU) | 8 (5) | 10 (6) | 8 (5) | 17 (6 ) | 6 (5) | 9 (5) | 10 (4) |
| | Cold Paste Viscosity (RVU) | 242 (26) | 248 (30) | 256 (5) | 237 (35) | 208 (25) | 205 (25) | 231 (23) |
| | Setback (RVU) | 109 (19) | 113 (17) | 118 (16) | 105 (18) | 87 (14) | 83 (17) | 101 (16) |
| | Peak Time (Minute) | 5.53 (0.54) | 5.59 (0.16) | 5.58 (0.47) | 5.10 (0.20) | 6 (1) | 5 (0) | 5.45 (0.41) |
| | Pasting Temperature (°C) | 76.8 (1.5) | 77.3 (2.0) | 77.7 | 76.0 (1.0) | 77 (4) | 76 (1) | 76.8 (1) |
| Red | Peak Viscosity (RVU) | 148 (9) | 122 (8) | 134 (19) | 141 (13) | 112 (23) | 106 (9) | 123(15) |
| | Hot Paste Viscosity (RVU) | 134 (6) | 121 (8) | 129 (17) | 132 (14) | 108 (20) | 104 (9) | 119 (12) |
| | Breakdown (RVU) | 14 (7) | 1 (0) | 5 (4) | 9 (3) | 4 (3) | 2 (1) | 4 (3) |
| | Cold Paste Viscosity (RVU) | 249 (13) | 214 (17) | 241 (32) | 238 (18) | 190 (33) | 181 (14) | 213 (27) |
| | Setback (RVU) | 115 (12) | 93 (9) | 112 (19) | 106 (12) | 82 (15) | 77 (6) | 94 (15) |
| | Peak Time (Minute) | 5.37 (0.36) | 6.57 (0.65) | 5.85 (0.65) | 5.47 (0.24) | 6 (1) | 6 (1) | 5.98 (0.39) |
| | Pasting Temperature (°C) | 78.0 (0.7) | 79.0 (1.3) | 78.1 (1.4) | 75.9 (1.2) | 76 (1) | 77 (1) | 77.2 (1.4) |
| Spanish Brown | Peak Viscosity (RVU) | 153 (13) | 143 (15) | 150 (12) | 148 (14) | 123 (10) | 131 (12) | 139 (12) |
| | Hot Paste Viscosity (RVU) | 143 (10) | 139 (12) | 144 (10) | 135 (17) | 121 (10) | 122 (9) | 132 (10) |
| | Breakdown (RVU) | 9 (6) | 5 (3) | 6 (3) | 14 (4) | 2 (1) | 9 (5) | 7 (5) |
| | Cold Paste Viscosity (RVU) | 249 (26) | 253 (22) | 264 (19) | 247 (26) | 210 (20) | 205 (25) | 236 (27) |
| | Setback (RVU) | 129 (18) | 114 (11) | 120 (11) | 113 (12) | 89 (11) | 83 (17) | 104 (17) |
| | Peak Time (Minute) | 5.45 (0.58) | 6.19 (0.84) | 5.59 (0.27) | 5.13 (0.26) | 6 (1) | 5 (0) | 5.58 (0.52) |
| | Pasting Temperature (°C) | 77.4 (0.6) | 78.2 (1.3) | 78.0 (0.8) | 75.7 (0.8) | 79 (1) | 76 (1) | 77.4 (1.5) |

**Table 26. Mean starch characteristics of lentil cultivars grown in the USA in 2019.**

| 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 | 136 | 127 | 9 | 239 | 112 | 5.09 | 76.7 |
| | Brewer | 133 | 127 | 6 | 227 | 101 | 5.90 | 78.5 |
| | CDC Impress* | 149 | 139 | 10 | 232 | 93 | 5.20 | 75.0 |
| | CDC Imvincible* | 144 | 138 | 6 | 244 | 106 | 5.67 | 76.6 |
| | CDC Richlea | 152 | 134 | 18 | 257 | 123 | 4.87 | 75.6 |
| | CDC Viceroy | 147 | 138 | 9 | 238 | 100 | 5.53 | 75.7 |
| | Eston* | 138 | 136 | 1 | 257 | 121 | 6.20 | 77.5 |
| | Merrit | 146 | 135 | 11 | 241 | 107 | 5.27 | 77.2 |
| | NDSU Eagle* | 156 | 145 | 11 | 278 | 134 | 5.47 | 75.0 |
| | Sage* | 138 | 136 | 1 | 289 | 153 | 6.13 | 76.6 |
| Red | CDC Maxim* | 138 | 136 | 2 | 268 | 132 | 6.00 | 77.5 |
| | Red Chief | 150 | 134 | 17 | 244 | 111 | 5.22 | 78.1 |
| Spanish Brown | Pardina | 153 | 143 | 9 | 272 | 129 | 5.45 | 77.4 |

* Value from only one sample.



# Sample Distribution

A total of 39 chickpea samples were collected from Idaho, Montana, North Dakota, South Dakota, and Washington between July and November 2019. Growing location, number of samples, market class, and genotype details of dry chickpea samples are provided in Table 27. CDC Orion (8), Bronic (8) and Sierra (16) accounted for the majority of the chickpea evaluated.

# Proximate Composition of Chickpea

The **moisture content** of chickpeas ranged from 8.9 to 16.6% in 2019 (Table 28). The mean moisture content of the samples was 11.6%, which is higher than the 5-year mean of 9.2%. Chickpeas grown in 2019 had a mean moisture content that was similar to chickpeas grown in 2014. The moisture content of several samples was above 16%. CDC Orion had the highest moisture content at 16.6% while the Sierra cultivar had the lowest moisture (8.9%). However, the mean moisture percentage of individual cultivars were all below 13% (Table 29). The moisture contents of all samples were below the 13% recommended for general storability. **Ash content** of chickpeas ranged from 2.1 to 3.1% with a mean of 2.6% (Table 28). The mean ash content of chickpeas grown in 2019 was comparable to ash contents of chickpea from other previous harvest years. CDC Frontier had the lowest ash content at 2.5% while Sawyer had the mean highest ash content at 2.8% (Table 29). However, single samples of Bronic had ash content as high as 3.1%. Chickpea mean **fat content** was 6.1% and ranged from 5.4 to 7.9% (Table 28). Literature reports indicate that chickpea has a fat content between 2 and 7%; therefore, the fat content of chickpeas grown in 2019 fall within the range reported by others but less than the fat content recorded in 2018.

Dylan cultivar had the highest (6.5%) fat content while Nash had the lowest (5.4%) fat content (Table 29). Nash also had the lowest fat percentage in 2018. Protein content of chickpeas ranged from 15.0 to 23.5%, with a mean of 19.4% (Table 28). The mean **protein content** of chickpea grown in 2019 was similar to the 5-year mean of 19.5%. The protein percentage from the 2017 harvested chickpea most closes matched the protein percentage of the chickpea harvested in 2019. Royal had the lowest (18.3%) protein content while Sawyer had the highest protein content at 20.6% (Table 29).

**Total starch content** of chickpea ranged from 36.6 to 45%, with a mean of 40.1% (Table 28). The mean total starch content of chickpeas grown in 2019 was similar (i.e. 40%) to the mean starch content observed in chickpea from the 2016 harvest year, but only slightly lower than the 5-year mean of 40.7%. The Sawyer cultivar had the lowest (39.1%) starch content while the highest (45%) was observed in the Dylan cultivar

**Table 27. Description of chickpea samples used in the 2019 pulse quality survey.**

| State | No. of Samples | Market Class | Cultivars |
|---|---|---|---|
| Idaho | 21 | Kabuli | Bronic<br>Sawyer<br>Sierra |
| Montana | 12 | Kabuli | CDC Orion<br>Sawyer<br>Sierra |
| North Dakota | 1 | Kabuli | CDC Orion |
| Washington | 5 | Kabuli | Dylan<br>CDC Frontier<br>Nash<br>Royal<br>Sierra |

Table 28. Proximate composition of Kabuli chickpeas grown in the USA, 2014-2019.

| Proximate Composition** | 2019 Range | 2019 Mean (SD) | 2018 Mean (SD) | 2017 Mean (SD) | 2016 Mean (SD) | 2015 Mean (SD) | 2014* Mean (SD) | 5-year Mean (SD) |
|---|---|---|---|---|---|---|---|---|
| Moisture (%) | 8.9-16.6 | 11.6 (2.6) | 8.8 (0.9) | 8.5 (0.9) | 8.7 (1.7) | 9 (1) | 11 (1) | 9.2 (1.0) |
| Ash (%) | 2.1-3.1 | 2.6 (0.2) | 2.8 (0.2) | 2.8 (0.3) | 2.7 (0.1) | 2.7 (0.1) | 2.5 (0.2) | 2.7 (0.1) |
| Fat (%) | 5.4-7.9 | 6.1 (0.5) | 7.2 (1.1) | 6.0 (0.4) | *** | *** | *** | nd |
| Protein (%) | 15.0-23.5 | 19.4 (1.9) | 20.8 (2.3) | 19.5 (2.0) | 18.3 (1.4) | 19 (1) | 20 (2) | 19.5 (1.0) |
| Starch (%) | 36.6-45.0 | 40.1 (1.8) | 41.1 (2.5) | 39.6 (2.0) | 40.0 (4.2) | 41 (5) | 42 (1) | 40.7 (1.0) |

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

# Physical Parameters of Chickpeas

Test weight, 1000 seed weight, water hydration capacity, percentage unhydrated seeds, swelling capacity, cooked firmness and color represent the physical parameters used to define physical quality. The data presented also include size distribution for the first time in 2019. Test weight ranged from 58-64 lbs/bu with a mean of 61 lbs/bu. This mean value is the same as the 5-year mean of 61 lbs/bu (Table 30). The test weights of individual cultivars ranged from 58 lbs/bu in Dylan to 62 lbs/bu in the Royal and Sawyer cultivars. The range and mean 1000 seed weight of chickpeas grown in 2019 were 320-623 g and 444 g, respectively (Table 30). The mean 1000 seed weight was significantly higher than the 5-year mean of 411 g. The Nash cultivar had a highest 1000 seed weight at 623 g while the Bronic cultivar had the lowest value at 352 g (Table 31).

Water hydration capacity of chickpeas ranged from 71 to 164%, with a mean of 102% (Table 30). The water hydration capacity of chickpeas from 2019 was essentially the same as the 5-year mean of 103%. Most of the individual cultivars had similar water hydration capacities. However, the Bronic cultivar had the highest water hydration capacity (109%) while Sierra had the lowest (100%) (Table 31).

Unhydrated seed percentage was 0%, which was less than the 5-year mean of 1% (Table 30). All of the cultivars had 0% mean unhydrated seed values and only a few samples had one unhydrated seeds after soaking (Table 31). The swelling capacity of chickpeas ranged from 71 to 164%, with a mean value of 138% (Table 30). The mean swelling capacity value was similar to chickpeas from 2015 and 2016 and higher than the 5-year mean of 128%. The Bronic and Nash cultivar had the greatest mean swelling capacity at 145% while the CDC Orion and Sierra cultivars had the lowest (135%). The swelling capacity of CDC Frontier cultivar has been evaluated since 2014. The swelling capacity of 105% (2014), 116% (2016), 134 (2018), 136% (2017, 2019) and 138% (2015) were observed over the 6-year period

Table 29. Mean proximate composition of chickpea cultivars grown in the USA, 2019.

| Cultivar | Moisture | Ash | Fat | Protein | Starch |
|---|---|---|---|---|---|
| | Concentration (%) | | | | |
| Bronic | 12.2 | 2.7 | 6.1 | 19.4 | 39.7 |
| CDC Frontier* | 11.0 | 2.5 | 5.7 | 19.6 | 41.8 |
| CDC Orion | 12.2 | 2.6 | 6.4 | 19.5 | 39.7 |
| Dylan* | 9.8 | 2.6 | 6.5 | 16.6 | 45.0 |
| Nash* | 10.7 | 2.7 | 5.4 | 18.8 | 42.1 |
| Royal* | 10.8 | 2.6 | 5.6 | 18.3 | 41.9 |
| Sawyer | 11.4 | 2.8 | 5.8 | 20.6 | 39.4 |
| Sierra | 11.1 | 2.6 | 6.0 | 19.5 | 40.1 |
| Unknown* | 12.3 | 2.6 | 6.4 | 19.3 | 39.1 |

* Value from only one sample of designated cultivar.



The cooked firmness of all chickpea ranged from 15.8 to 32.9 N/g, with a mean value of 20.7 N/g (Table 30). Among the cultivars, Sawyer had the lowest cooked firmness (17.7 N/g) while the CDC Orion cultivar was the firmest (Table 31). Retention of chickpea on a series of sieves was used to determine chickpea size. This was the first year of this test. The mean retentions of 64.2, 29.1, 6.1 and 0.6 % on the 22/64, 20/64, 18/ 64 and passed through the 18/64-inch sieves were observed in the 2019 chickpea, respectively (Table 30). The highest percentage retention of the samples on the 22/64-inch sieve was observed for the cultivars Dylan (97%), Royal (94%) and Nash (93%). Bronic had the lowest (19.1%) retention on the 22/64-inch sieve (Table 31). However, Bronic had the highest retention of the 20/64 and 18/64-inch sieves, which supports the smaller size of Bronic compared to other chickpeas.

Table 30. Physical parameters of chickpeas grown in the USA, 2014-2019.

| Physical Parameter | 2019 Range | 2019 Mean (SD) | 2018 Mean | 2017 Mean | 2016 Mean | 2015 Mean | 2014* Mean | 5-year Mean (SD) |
|---|---|---|---|---|---|---|---|---|
| Test Weight (lb/Bu) | 58-64 | 61.0 (1.0) | 62.0 (1.4) | 61 (2) | 61 (2) | 60 | 61 | 61 (1) |
| 1000 Seed Wt | 320-623 | 444 (74) | 410 (71) | 421 (72) | 410 (106) | 404 | 403 | 411 (24) |
| Water Hydration Capacity (%) | 79-118 | 102 (8) | 102 (10) | 104 (13) | 105 (15) | 108 | 113 | 103 (3) |
| Unhydrated Seeds (%) | 0-0 | 0 (0) | 0 (2) | 0 (1) | 1 (1) | 0 | 0 | 1 (2) |
| Swelling Capacity (%) | 71-164 | 138 (15) | 130 (14) | 129 (27) | 141 (12) | 136 | 105 | 128 (14) |
| Cooked Firmness (N/g) | 15.8-32.9 | 20.7 (3.8) | 27.9 (6.1) | 26 (5) | 22.0 (3.0) | 19.7 | ** | nd |
| % of Sample Retained on 22/64 Sieve | 2.5-100 | 64.2 (28.3) | ** | ** | ** | ** | ** | nd |
| % of Sample Retained on 20/64 Sieve | 0-69 | 29.1 (20.8) | ** | ** | ** | ** | ** | nd |
| % of Sample Retained on 18/64 Sieve | 0-41 | 6.1 (10.0) | ** | ** | ** | ** | ** | nd |
| % of Sample Passed Through an 18/64 Sieve | 0-3.5 | 0.6 (1.0) | ** | ** | ** | ** | ** | nd |

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

Table 31. Mean physical properties of chickpea cultivars grown in the USA, 2019.

| Cultivar | Test Weight (lb/Bu) | 1000 Seed Wt | Water Hydration Capacity (%) | Unhydrated Seeds (%) | Swelling Capacity (%) | Cooked Firmness (N/g) | % of Sample Retained on 22/64 Sieve | % of Sample Retained on 20/64 Sieve | % of Sample Retained on 18/64 Sieve | % of Sample Passed Through an 18/64 Sieve |
|---|---|---|---|---|---|---|---|---|---|---|
| Bronic | 61 | 352 | 109 | 0 | 145 | 19.8 | 19.1 | 56.8 | 22.3 | 1.9 |
| CDC Frontier* | 61 | 365 | 102 | 0 | 136 | 21.2 | 42.0 | 50.0 | 8.0 | 0.0 |
| CDC Orion | 61 | 424 | 101 | 0 | 135 | 25.3 | 65.9 | 32.7 | 1.4 | 0.0 |
| Dylan* | 58 | 605 | 102 | 0 | 143 | 20.3 | 97.0 | 2.0 | 0.0 | 1.0 |
| Nash* | 60 | 623 | 107 | 0 | 145 | 20.6 | 93.0 | 6.5 | 0.5 | 0.0 |
| Royal* | 62 | 563 | 108 | 0 | 144 | 20.2 | 94.0 | 5.0 | 1.0 | 0.0 |
| Sawyer | 62 | 394 | 105 | 0 | 144 | 17.7 | 46.0 | 49.3 | 3.8 | 1.0 |
| Sierra | 60 | 479 | 100 | 0 | 135 | 19.3 | 81.8 | 15.8 | 2.0 | 0.3 |
| Unknown* | 60 | 516 | 94 | 0 | 141 | 21.5 | 96.5 | 3.5 | 0.0 | 0.0 |

* Value from only one sample of cultivar.

Color quality was measured using L, a, and b values and from these values a color difference was determined on chickpeas before and after soaking (Table 32). Color quality indicated that the lightness (i.e., L) of the chickpeas from 2019 was similar to the chickpeas from 2018 (Table 32). In 2019, the “a” value of 5.17 was lower than values from the previous 5 years. This indicates that the chickpeas from 2019 were slightly greener than previous samples. The “b” value for chickpeas from 2019 indicated a less yellow color compared to chickpea samples from 2014 to 2018. The color of the chickpeas changed after the soaking process. Similar to peas and lentils, chickpea became lighter as evidenced by the higher L values (Table 32) compared to pre-soaked chickpeas.

Table 32. Color quality of chickpeas grown in the USA before and after soaking, 2014-2019.

| Color Scale* | Mean (SD) Color Values: Before Soaking 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | After Soaking 2019 | 2018 | 2017 | 2016 | 2015 | 2014 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| L (lightness) | 55.69 (1.73) | 55.01 (2.38) | 53.01 (3.01) | 66.86 (4.22) | 63.32 (2.61) | 81 (12) | 56.16 (1.07) | 56.68 (1.68) | 57.27 (1.74) | 55.57 (1.04) | 70.33 (4.07) | 60.49 (8.02) |
| a (red-green) | 5.17 (0.61) | 8.55 (1.43) | 9.09 (1.72) | 7.83 (1.61) | 5.55 (0.76) | 11 (2) | 5.21 (0.42) | 11.35 (1.05) | 10.85 (0.98) | 11.44 (1.04) | 6.97 (1.28) | 7.01 (0.44) |
| b (yellow-blue) | 10.95 (0.80) | 21.28 (1.99) | 21.14 (2.07) | 22.19 (2.55) | 14.19 (0.45) | 28 (4) | 16.99 (6.41) | 34.94 (2.20) | 34.36 (2.41) | 34.11 (2.31) | 31.47 (7.70) | 29.26 (0.91) |
| Color Difference | 6.41 (1.13) | 13.69 (1.96) | 13.80 (1.78) | 10.83 (6.02) | 15.47 (3.10) | ** | | | | | | |

*color scale L (lightness) axis – 0 is black and 100 is white; a (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

This same trend occurred in samples from previous years except 2014. The redness (i.e., "a" value) did change slightly after soaking. In contrast, chickpeas from all years became yellower (i.e., increased "b" value) after soaking. The color difference between the pre- and post-soaked chickpea from 2019 was significantly smaller than the color difference for samples from previous years (Table 32).

Among cultivars, Dylan had the highest L value (59.66) while Bronic had the lowest (i.e. 53.86). The Dylan cultivar also had the highest L value among chickpea cultivars in 2018. Dylan had the lowest "a" and "b" values among cultivars (Table 33). The highest yellowness value was observed in CDC Orion (Table 33). Visual observations support the color value differences as the Dylan cultivar appeared whiter in color than other cultivars. Most cultivars underwent an increase in lightness during soaking, as evidenced by the higher L value of the soaked sample. However, several samples had decreased L values, which may be the result the yellow cotyledon color impacting lightness. An increased yellowness was observed for all cultivars. The greatest color difference was observed in the Bronic cultivar (Table 39). The change in color observed in the Bronic cultivar was likely due to the significant increase in lightness and yellowness during the soaking.

# Pasting Properties

Peak, hot and cold paste viscosities of chickpeas grown in 2019 were either similar or slightly above the 5-year mean values (Table 34). The viscosity data indicated that the pasting properties of the 2019 chickpea crop were most similar to the chickpeas from 2018. The peak time was longer for samples from 2019 compared to other crop years. The pasting temperature was slightly higher for the chickpeas from 2019 compared to the 5-year mean pasting temperature. Of the quality attributes tested, pasting properties were least like chickpea from other harvest years. Peak, hot and cold paste viscosities of the Royal chickpea cultivar were greatest among cultivars tested (Table 35). In contrast, the cultivar CDC Orion had the lowest peak, hot paste and cold paste viscosities. Pasting properties were similar among other cultivars tested. Pasting temperature was lowest (72.5 °C) and highest (76.7 °C) for Royal and both Sawyer and CDC Frontier cultivars, respectively.



Table 33. Mean color quality of chickpea cultivars grown in the USA, 2019.

| Cultivar | Mean Color Values**: Before Soaking L | a | b | After Soaking L | a | b | Color Difference |
|---|---|---|---|---|---|---|---|
| Bronic | 53.86 | 5.75 | 10.92 | 56.29 | 5.79 | 18.58 | 8.06 |
| CDC Frontier* | 54.50 | 5.87 | 10.84 | 56.34 | 5.76 | 18.12 | 7.54 |
| CDC Orion | 55.17 | 5.49 | 11.65 | 56.55 | 5.22 | 16.81 | 5.86 |
| Dylan* | 59.66 | 3.92 | 9.61 | 55.49 | 4.79 | 15.73 | 7.45 |
| Nash* | 57.42 | 4.82 | 10.42 | 54.41 | 5.25 | 16.16 | 6.50 |
| Royal* | 55.89 | 5.06 | 10.18 | 55.19 | 5.60 | 16.60 | 6.56 |
| Sawyer | 55.81 | 5.28 | 11.29 | 57.13 | 4.94 | 17.31 | 6.70 |
| Sierra | 56.57 | 4.74 | 10.77 | 56.03 | 4.87 | 16.39 | 5.75 |
| Unknown* | 54.61 | 4.83 | 10.42 | 55.43 | 5.14 | 16.22 | 5.86 |

* Value from only one sample of cultivar. **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 34. Starch characteristics of chickpeas grown in the USA, 2014-2019.

| Starch Characteristic | Year: 2019 Range | 2019 Mean (SD) | 2018 Mean (SD) | 2017 Mean (SD) | 2016 Mean (SD) | 2015 Mean (SD) | 2014 Mean (SD) | 5-year Mean (SD) |
|---|---|---|---|---|---|---|---|---|
| Peak Viscosity (RVU) | 94-179 | 136 (18) | 131 (15) | 126 (15) | 139 (23) | 126 (15) | 143 (7) | 134 (7) |
| Hot Paste Viscosity (RVU) | 92-165 | 131 (16) | 125 (12) | 124 (14) | 134 (22) | 124 (14) | 138 (7) | 130 (6) |
| Breakdown (RVU) | 1-19 | 5 (4) | 6 (6) | 3 (2) | 6 (4) | 3 (2) | 5 (1) | 5 (1) |
| Cold Paste Viscosity (RVU) | 141-266 | 198 (30) | 187 (29) | 185 (24) | 214 (70) | 185 (24) | 210 (2) | 198 (13) |
| Setback (RVU) | 24-105 | 68 (18) | 62 (20) | 62 (13) | 80 (43) | 62 (13) | 17 (2) | 58 (24) |
| Peak Time (Minute) | 4.80-7.00 | 6.33 (0.57) | 6.06 (0.65) | 6 (0) | 6.04 (0.61) | 6 (0) | 6 (0) | 6.09 (1) |
| Pasting Temperature (°C) | 71.8-78.3 | 75.6 (1.6) | 75.8 (1.9) | 76 (2) | 74.5 (1.3) | 76 (2) | 74 (3) | 75.1 (1) |

Table 35. Mean starch characteristics of Kabuli chickpea cultivars grown in the USA, 2019.

| Cultivar | Peak Viscosity (RVU) | Hot Paste Viscosity (RVU) | Breakdown (RVU) | Cold Paste Viscosity (RVU) | Setback (RVU) | Peak Time (Min) | Pasting Temperature (°C) |
|---|---|---|---|---|---|---|---|
| Bronic | 141 | 135 | 5 | 202 | 66 | 6.3 | 76.2 |
| CDC Frontier* | 143 | 142 | 1 | 230 | 88 | 6.3 | 74.2 |
| CDC Orion | 127 | 123 | 4 | 179 | 55 | 6.4 | 74.9 |
| Dylan* | 179 | 161 | 19 | 266 | 105 | 5.4 | 75.2 |
| Nash* | 143 | 134 | 9 | 195 | 62 | 6.1 | 76.7 |
| Royal* | 145 | 140 | 5 | 208 | 68 | 6.0 | 74.0 |
| Sawyer | 136 | 126 | 10 | 199 | 72 | 6.4 | 76.7 |
| Sierra | 135 | 130 | 5 | 200 | 70 | 6.3 | 75.9 |
| Unknown* | 119 | 116 | 2 | 191 | 75 | 7.0 | 72.5 |

# Canning Quality

Canning quality was completed only on pea and chickpea. Lentil tend not to be canned unless they are a component of a soup. Therefore, the focus of this evaluation was on pea and chickpea. The quality evaluation includes hydration capacity, swelling capacity, canned firmness and color evaluation. Hydration capacity and swelling capacity were completed following the soak test method. The only difference was that the hydration and swelling capacity was measured on a canned pea or chickpea.

## Peas

The mean water hydration capacity of canned peas was 260% for all peas (Table 36). This value was slightly higher than the water hydration capacity of peas from the 2018 crop year. A difference in water hydration capacity between the green (254%) and yellow (265%) market classes was observed. Furthermore, Winter (216%) and Marrowfat (230%) were also canned and found to have lower water hydration capacities. In comparison, water hydration capacities of peas in the soak test were 99 and 94% for green and yellow peas, respectively. Water hydration capacities ranged from 140 to 377% for all peas. In green peas, Hampton had the lowest water hydration capacity at 151% while Majoret had the highest at 304%. In yellow cultivars, CDC Inca and DS Admiral had the lowest (207%) water hydration capacities while the CDC Spectrum cultivar had the highest (377%) value (Table 37). The results of the soak test did not directly translate into similar results in the canning water hydration in the context of an order.

The swelling capacity is the amount of swelling that occurred during rehydration of the dry pea and the canning operation. The swelling capacity of all peas ranged from 116 to 256%, with a mean value of 204% (Table 36). The green pea cultivars Aragorn and Arcadia had the lowest (161%) and highest (213%) swelling capacities, respectively. In yellow cultivars, LG Amigo had the lowest swelling capacity at 174% while Mystique had the highest at 231%. Different cultivars accounted for the upper and lower swelling capacities between the canning and soak tests. The canned firmness values of peas were significantly lower than the cooked firmness values of soaked peas. The mean canned firmness value of all peas was 6.0 N/g (Table 36). In comparison, the mean cooked firmness for all peas was 21 N/g (Table 9). As expected, the canned peas were less firm than the cooked peas. The Empire (Green) cultivar was the least firm while Hampton (green) was the firmest (Table 37). Hampton also had the highest canned firmness in 2018.

The color of the dry pea changed after the canning process. The color difference fell between 4.40 and 15.70, with a mean value of 9.28 for all peas, and 10.04 and 8.94 for the green and yellow market classes, respectively. The marrowfat pea had a color difference of 12.06. In this sample, a clear color change from a white appearance to a green appearance was noticeable. A slightly higher color difference was observed in canned peas compared to soaked peas. The lightness decreased during canning for both green and yellow market classes. In the soak test, only the green cultivars darkened upon soaking. The greatest color difference was observed in the AAC Comfort cultivar after canning (Table 37) while the Shamrock cultivar had the lowest color difference among the green cultivars. In the yellow cultivars, Bridger and Mystique had the highest and lowest color differences, respectively (Table 37).

**Table 36. Mean physical and color parameters of canned dry pea grown in 2019.**

| | | | | Mean Color Values* | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Before Soaking | | | After Soaking | | | |
| Sample** | Hydration Capacity (%) | Swelling Capacity (%) | Canned Firmness (N/g) | L | a | b | L | a | b | Color Difference |
| All | 260 | 204 | 6.0 | 56.71 | 2.09 | 9.85 | 48.99 | 2.43 | 14.43 | 9.28 |
| Green | 254 | 200 | 6.4 | 53.40 | -1.88 | 7.00 | 45.33 | -0.63 | 12.41 | 10.04 |
| Yellow | 265 | 206 | 5.7 | 58.63 | 4.10 | 11.39 | 51.06 | 3.95 | 15.65 | 8.94 |
| Winter | 214 | 204 | 7.4 | 46.22 | -0.59 | 4.92 | 40.09 | 1.73 | 8.22 | 7.83 |
| Marrowfat | 230 | 229 | 3.7 | 60.64 | 1.61 | 10.43 | 48.62 | 1.01 | 10.76 | 12.06 |

*color scale: L (lightness) axis – 0 is black and 100 is white; a (red-green) axis – positive values are red, negative values are green, and zero is neutral; and b (yellow-blue) axis – positive values are yellow, negative values are blue, and zero is neutral. **Includes all pea samples or separated into market class.



**Table 37. Mean physical and color parameters of canned dry pea cultivars grown in 2019.**

| | | | | | Mean Color Values* | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Before Soaking | | | After Soaking | | | |
| Market Class | Cultivar | Hydration Capacity (%) | Swelling Capacity (%) | Canned Firmness (N/g) | L | a | b | L | a | b | Color Difference |
| Green | AAC Comfort** | 209 | 197 | 7.4 | 55.01 | -2.28 | 7.42 | 42.11 | -0.19 | 10.77 | 13.51 |
| | Aragorn** | 242 | 161 | 7.4 | 54.83 | -2.69 | 6.96 | 44.71 | -1.30 | 13.50 | 12.14 |
| | Arcadia | 266 | 213 | 5.3 | 53.99 | -1.84 | 6.95 | 46.24 | -0.56 | 12.91 | 10.07 |
| | Ariel** | 274 | 192 | 6.6 | 55.14 | -2.37 | 6.64 | 45.53 | -1.19 | 13.01 | 11.59 |
| | Banner | 234 | 193 | 7.7 | 51.43 | -2.43 | 7.01 | 43.03 | -0.53 | 10.93 | 9.71 |
| | CDC Greenwater | 281 | 205 | 6.1 | 55.04 | -1.29 | 6.62 | 45.29 | -0.08 | 12.46 | 11.48 |
| | Columbian** | 246 | 201 | 9.4 | 53.79 | -2.66 | 7.36 | 44.36 | -1.29 | 12.09 | 10.69 |
| | Empire** | 293 | 205 | 3.9 | 54.61 | -0.85 | 6.28 | 47.16 | -0.11 | 13.17 | 10.17 |
| | Ginny | 217 | 184 | 7.3 | 53.71 | -1.94 | 7.05 | 44.30 | -0.89 | 11.78 | 10.66 |
| | Greenwood | 249 | 188 | 6.1 | 51.38 | -1.99 | 6.74 | 45.62 | -1.06 | 12.86 | 8.57 |
| | Hampton | 151 | 168 | 12.2 | 53.46 | -2.13 | 7.04 | 42.82 | -0.23 | 10.25 | 11.46 |
| | Majoret | 304 | 206 | 5.8 | 54.75 | -1.56 | 7.03 | 46.73 | -0.50 | 13.00 | 10.13 |
| | Pro 131-7123 | 261 | 203 | 5.4 | 51.52 | -2.48 | 6.84 | 43.83 | -1.58 | 12.33 | 9.54 |
| | Shamrock | 269 | 198 | 5.2 | 52.94 | -0.87 | 8.16 | 48.26 | -0.25 | 13.40 | 7.15 |
| Yellow | AAC Carver | 268 | 209 | 8.0 | 59.61 | 3.91 | 11.53 | 51.62 | 3.76 | 17.18 | 9.90 |
| | AAC Chrome** | 274 | 211 | 5.3 | 58.27 | 3.99 | 10.17 | 52.86 | 3.47 | 15.63 | 7.70 |
| | AAC Profit | 299 | 228 | 4.5 | 57.99 | 4.51 | 11.40 | 52.00 | 3.15 | 14.86 | 7.51 |
| | AC Agassiz | 270 | 216 | 4.6 | 59.25 | 4.14 | 11.21 | 51.26 | 3.76 | 15.22 | 9.12 |
| | AC Earlystar | 291 | 227 | 4.4 | 60.68 | 3.94 | 12.01 | 51.16 | 4.04 | 16.18 | 10.54 |
| | Bridger** | 248 | 179 | 6.0 | 62.14 | 4.85 | 11.92 | 50.66 | 3.80 | 16.02 | 12.42 |
| | CDC Amarillo | 285 | 214 | 5.8 | 58.79 | 4.21 | 11.84 | 50.61 | 4.07 | 16.46 | 9.03 |
| | CDC Golden** | 253 | 203 | 9.2 | 56.87 | 4.19 | 11.56 | 50.36 | 4.26 | 16.25 | 8.03 |
| | CDC Inca | 207 | 220 | 10.0 | 57.14 | 3.91 | 11.45 | 48.41 | 3.73 | 14.75 | 9.52 |
| | CDC Meadow** | 252 | 210 | 7.4 | 58.33 | 4.11 | 11.29 | 50.31 | 5.61 | 18.52 | 10.91 |
| | CDC Saffron** | 279 | 197 | 6.0 | 61.33 | 3.84 | 11.65 | 49.76 | 4.79 | 14.67 | 12.09 |
| | CDC Spectrum | 377 | 205 | 9.4 | 59.20 | 3.81 | 11.17 | 49.77 | 3.01 | 15.13 | 10.05 |
| | Delta** | 276 | 180 | 5.5 | 61.53 | 4.47 | 11.97 | 52.15 | 3.34 | 17.66 | 11.03 |
| | DL Apollo** | 281 | 197 | 4.0 | 60.45 | 3.09 | 12.69 | 51.93 | 3.66 | 16.61 | 9.74 |
| | DS Admiral** | 207 | 205 | 9.9 | 61.27 | 4.30 | 11.25 | 49.90 | 4.75 | 15.85 | 12.30 |
| | Durwood | 260 | 206 | 5.5 | 59.42 | 3.64 | 11.31 | 50.40 | 3.85 | 15.91 | 10.37 |
| | Hyline** | 285 | 210 | 4.4 | 60.39 | 3.54 | 11.76 | 50.41 | 3.74 | 16.00 | 10.90 |
| | Jetset** | 280 | 213 | 4.5 | 60.23 | 3.70 | 11.57 | 50.28 | 3.71 | 16.26 | 11.01 |
| | Korando | 240 | 213 | 6.5 | 60.46 | 4.29 | 10.82 | 49.86 | 3.04 | 14.52 | 11.47 |
| | LG Amigo** | 264 | 174 | 6.4 | 61.10 | 4.74 | 11.56 | 53.60 | 3.47 | 18.10 | 8.48 |
| | LG Sunrise** | 276 | 198 | 6.5 | 60.29 | 3.49 | 11.95 | 52.09 | 3.34 | 17.39 | 9.48 |
| | Montech 4152** | 271 | 199 | 3.3 | 57.96 | 3.42 | 9.94 | 51.41 | 4.23 | 15.00 | 8.32 |
| | Mystique | 259 | 231 | 6.0 | 58.67 | 4.63 | 10.95 | 53.15 | 4.58 | 14.16 | 6.59 |
| | Navarro** | 260 | 178 | 6.7 | 62.26 | 4.36 | 11.95 | 52.17 | 3.92 | 16.58 | 11.13 |
| | NDP121587** | 315 | 242 | 4.0 | 57.98 | 4.17 | 10.58 | 49.44 | 3.88 | 15.07 | 9.65 |
| | Nette 2010 | 258 | 203 | 5.4 | 57.21 | 3.92 | 11.46 | 51.11 | 3.83 | 15.34 | 7.76 |
| | Salamanca | 262 | 202 | 4.7 | 58.18 | 4.30 | 11.09 | 51.15 | 4.22 | 15.26 | 8.45 |
| | Spider | 276 | 210 | 6.1 | 58.43 | 3.67 | 11.38 | 50.63 | 4.00 | 15.79 | 9.10 |
| | Summit** | 278 | 201 | 3.7 | 57.81 | 4.06 | 11.78 | 52.46 | 2.56 | 16.34 | 7.19 |
| | SW Midas | 209 | 179 | 9.5 | 57.65 | 3.86 | 11.40 | 51.21 | 4.77 | 16.48 | 8.31 |
| | Treasure | 283 | 215 | 5.4 | 58.34 | 4.42 | 12.39 | 51.31 | 3.98 | 16.32 | 8.33 |
| | Unknown | 227 | 171 | 6.4 | 58.35 | 4.34 | 11.27 | 50.34 | 3.99 | 16.04 | 9.46 |
| Winter | Austrian Winter | 220 | 216 | 11.0 | 43.08 | 1.06 | 3.75 | 35.66 | 4.33 | 4.87 | 8.19 |
| | Vail | 208 | 192 | 3.8 | 49.36 | -2.25 | 6.09 | 44.52 | -0.88 | 11.57 | 7.47 |
| Marrowfat | Orka** | 230 | 229 | 3.7 | 60.64 | 1.61 | 10.43 | 48.62 | 1.01 | 10.76 | 12.06 |

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

## Chickpeas

The mean water hydration capacity of canned chickpea was 166% (Table 38). The water hydration capacity canned chickpea was higher than that observed in the soak test (102%). Water hydration capacities ranged from 138 to 193% for all chickpea. CDC Orion had the lowest water hydration capacity at 159% while Dylan had the highest at 182%. In 2018 these two cultivars also had the lowest and highest water hydration capacity. In the soak test, CDC Orion also had the second lowest water hydration capacity, which closely matched the outcome of the canning results. However, Dylan did not have the highest water hydration capacities in the soak test, as was observed in the canning water hydration capacity (Table 38). The swelling capacity is the amount of swelling that occurred during rehydration of the dry chickpea and the canning operation. The swelling capacity of all chickpeas ranged from 166 to 215%, with a mean value of 192% (Table 38). CDC Frontier had the lowest mean swelling capacity at 182% while Nash had the highest at 215%. Nash also had the highest swelling capacity in canned chickpea in 2018. The mean water hydration and swelling capacities were both higher in the 2019 crop year compared chickpea from 2018.

The canned firmness values of chickpeas were significantly lower than the cooked firmness values of soaked chickpeas. The mean canned firmness value of all chickpeas was 6.7 N/g. In comparison, the mean cooked firmness for all chickpeas was 20.7 N/g (Table 30). As expected, the canned chickpeas were less firm than the cooked chickpeas. The Bronic and Sawyer cultivars were the least firm while Dylan was the firmest (Table 38). The color of the chickpeas changed after the canning process. The color difference fell between 5.04 and 9.03, with a mean value of 6.65 for all chickpeas. A slightly lower color difference was observed in soaked (6.41) chickpeas compared to canned (6.65) chickpeas. The L or lightness decreased during canning (Table 38). The L value of chickpea also decreased in the soak test. The greatest color difference was observed in the Dylan cultivar after canning (Table 38). The substantial reduction in the L value likely contributed the higher color difference value. The Dylan cultivar also had the greatest color reduction in the 2018 canning evaluation. The Bronic cultivar had the lowest color difference after canning.

**Table 38. Mean physical and color parameters of canned dry chickpea cultivars grown in 2019.**

| | | | | Mean Color Values* | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Before Soaking | | | After Soaking | | | |
| Cultivar** | Hydration Capacity (%) | Swelling Capacity (%) | Canned Firmness (N/g) | L | a | b | L | a | b | Color Difference |
| Bronic | 174 | 196 | 6.1 | 54.52 | 5.92 | 10.97 | 47.32 | 5.40 | 13.19 | 7.62 |
| CDC Frontier** | 161 | 182 | 7.5 | 54.34 | 5.91 | 10.87 | 46.46 | 6.01 | 12.41 | 8.03 |
| CDC Orion | 159 | 197 | 7.3 | 55.12 | 5.68 | 11.57 | 47.40 | 4.12 | 11.34 | 8.67 |
| Dylan** | 182 | 204 | 8.0 | 59.72 | 3.92 | 9.40 | 44.99 | 3.82 | 10.62 | 14.78 |
| Nash** | 166 | 215 | 6.4 | 57.68 | 4.89 | 10.56 | 44.73 | 3.95 | 11.13 | 13.00 |
| Royal** | 166 | 192 | 7.7 | 55.96 | 5.26 | 10.16 | 44.95 | 4.38 | 10.60 | 11.05 |
| Sawyer | 171 | 207 | 6.1 | 56.63 | 5.28 | 11.34 | 46.60 | 5.06 | 11.60 | 10.44 |
| Sierra | 161 | 186 | 6.4 | 56.90 | 4.82 | 10.62 | 46.83 | 4.20 | 11.18 | 10.11 |
| Unknown** | 158 | 180 | 7.2 | 55.05 | 5.18 | 10.50 | 45.37 | 3.97 | 11.81 | 9.84 |

*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.



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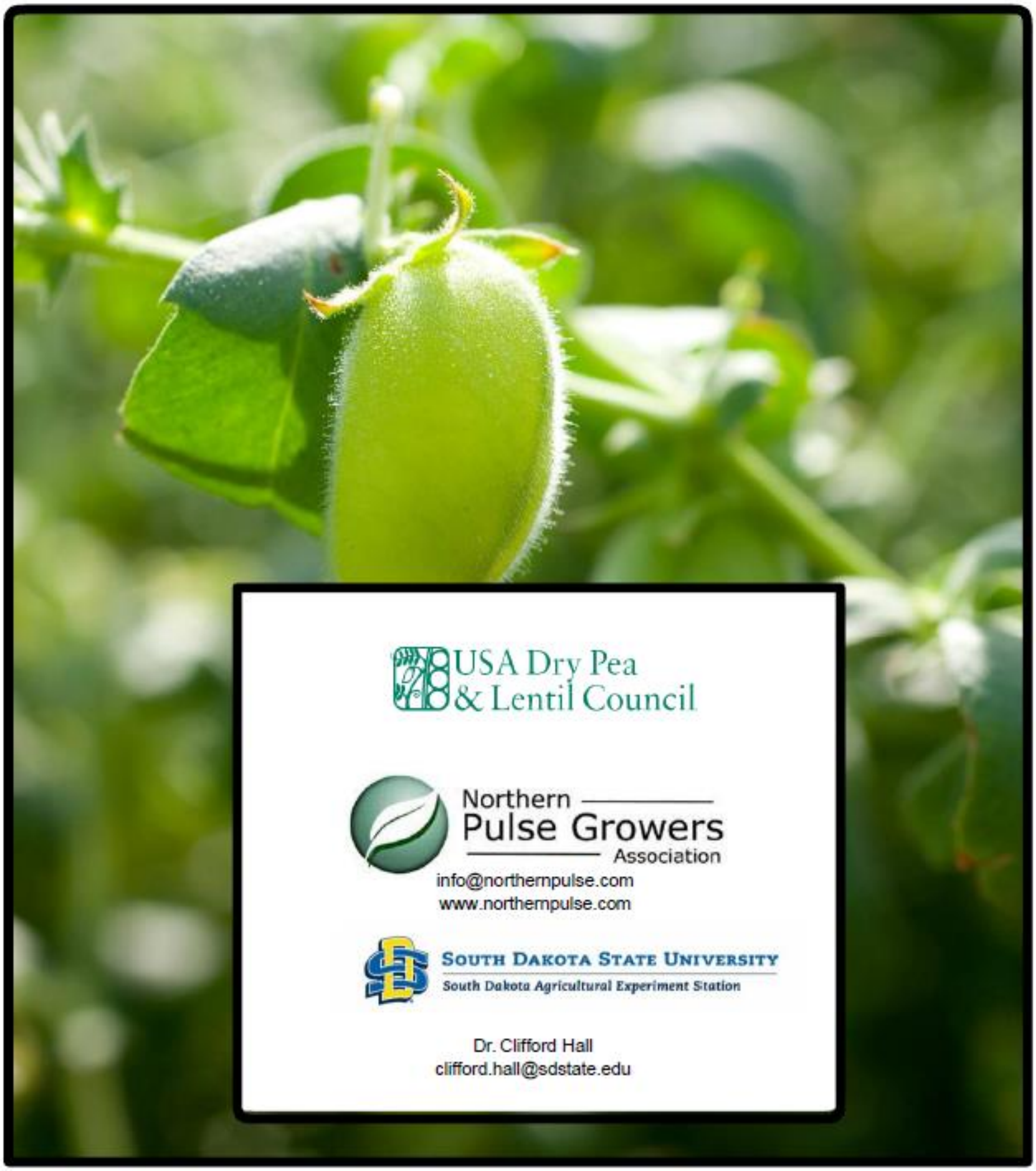

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