

# 2018 North Dakota Soybean Quality Survey

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## Summary

2018 was a year of surprises including **wet weather** along with the early arrival of winter, which has led to **a tough harvest** season. Production of the 2018 crop has marked **another record** due to **improved yield** despite acreage being down at both national and state levels. Especially notable quality of the 2018 crop is the below average levels of **protein** and oil, and higher than the average **amino acid** content. **Fatty acid** contents remain relatively similar to the previous year except record high **linoleic acid** content. Higher than the average soluble sugar especially stachyose is recorded as well.

## Sample collection

Nine agricultural districts serve as the basis for a comparison of crop quality data (Figure 1). A total of 250 samples were collected from 42 counties and eight agricultural districts in North Dakota by the United States Department of Agriculture-National Agricultural Statistics Service (USDA-NASS). Number of samples collected from each county is determined based on the soybean production from previous year which is calculated by the NASS. Due to the lack of soybean production in the Southwest district, no samples were collected.

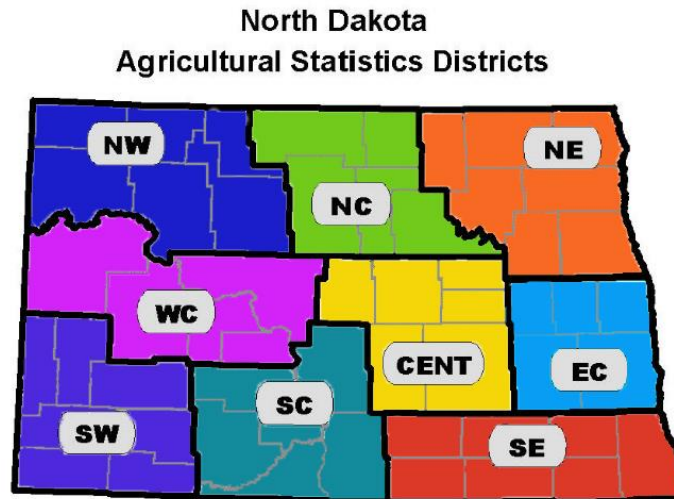


Figure 1. North Dakota agricultural districts

Table 1. North Dakota agricultural districts, number of samples collected and percent

District	Abbreviation	Number of Sample	% Distribution
Central	CENT	37	14.8
East Central	EC	53	21.2
North Central	NC	25	10
North East	NE	39	15.6
North West	NW	16	6.4
South Central	SC	10	4
South East	SE	55	22
West Central	WC	12	4.8
	Unknown	3	1.2
	<b>Total</b>	<b>250</b>	<b>100</b>



## Analysis method

Moisture, proximate (protein, oil ash and fiber), color, test weight, soluble sugar, fatty acid profile and amino acid profile were analyzed as quality attributes of North Dakota soybeans. Test weight and moisture were analyzed by the DICKEY-John Grain Analysis Computer GAC 2500 UGMA (Auburn, IL), based on the AACC method 55-10 (AACC, 1999). This was done immediately after the soybean samples were received. Color analysis was performed with a Minolta color analyzer CR-410 (Ramsey, NJ). CIE 1976 (L\*, a\*, b\*) color space, with which brightness (L\*), redness (a\*) and yellowness (b\*) values were determined. Proximate, soluble sugar, fatty acid and amino acid profile were evaluated using Perten DA7250 Near-InfraRed Spectroscopy (NIRS) (Huddinge, Sweden) with a calibration developed at the University of Minnesota and funded by the Minnesota Soybean Research and Promotion Council. The soybeans collected were ground into coarse flour using Perten Laboratory Mill 3600, and analyzed on the NIR to obtain proximate, soluble sugar, fatty acid and amino acid profile. Whole beans were used to obtain initial moisture, test weight and color. This NIR method was also utilized by Miller-Garvin and Naeve (2018) for the United States Soybean Crop Quality Report funded by the United States Soybean Export Council (USSEC). Through a collaborative effort as a soybean consortium, the North Dakota soybean quality data collected from the Perten DA 7250 contributes to the soybean calibration along with various universities in the nation. The calibration is updated annually reflecting the data collected from the previous crop year’s samples.

## 2018 Soybean Production

According to the data provided by USDA-NASS, 2018 U.S. soybean production was 4.6 billion bushels (Bu) or 125 million metric tons (MT), which was 4.3% higher than the previous year and the highest production on the record. Both the areas planted (89.4 million Bu or 36.1 million hectare (HA)) and harvested (88.3 million Bu or 35.8 million HA) declined yet yield increased at 52.1 Bu per acre or 3.5 MT per HA, helping boost the overall production. This was exactly opposite from 2017 when yield was low yet the acreages were at the record high.

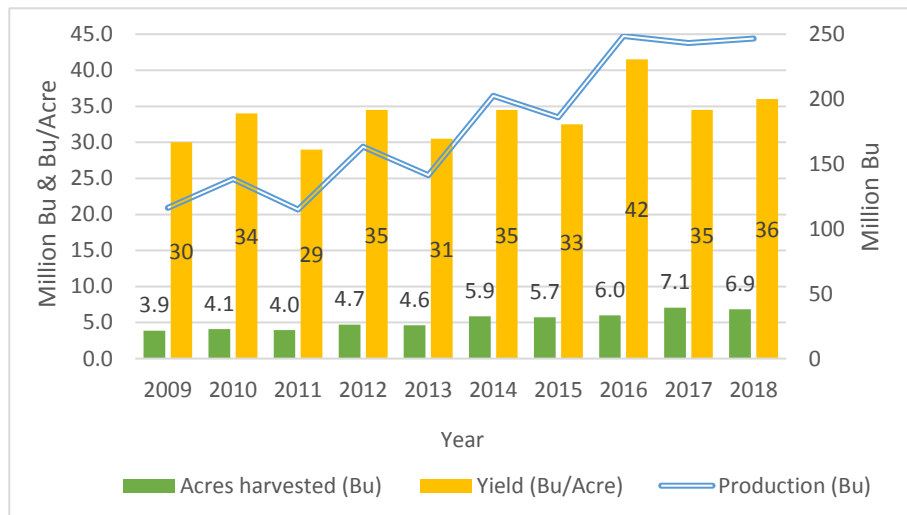


Figure 2. North Dakota soybean yield, harvest and production data between 2009 and 2018

A similar trend was observed at the state level. Soybean production at the state of ND was at 246.6 million Bu or 6.71 million MT with 1.4% increase from the previous year (Figure 2). Both acres planted and harvested experienced 2.8% reduction from the previous year at 6.90 million Bu or 2.79 million HA and 6.85 million Bu or 2.77 million HA, respectively. Despite the reduction, 4.4% increase in yield at 36 Bu per acre or 2.42 MT per HA helped retain the production value at near record high level which is the same trend as the national level.

### 2018 North Dakota Weather and Crop Summary

Figure 3 and 4 show plant and harvest progress, respectively. 2018 season started with cool and wet spring months. According to the North Dakota State Climate Office (NDSCO), the average temperature of 2018 spring (March through May) was 39.3 F, which was 2 F cooler than the 29-year average from 1981 to 2010. The average precipitation was 3.72 inches, which was 0.86 inch less than the 29-year average. The weather caused a slight delay in planting yet warm temperature in the later season helped accelerate plant growth. The average temperature and precipitation of 2018 summer (June through August) were 68.1 F and 8.19 inches which were 1.4 F warmer and 0.61 inch more than the 29-year average, respectively (NDSCO). Temperature took a drastic turn in the fall with lower than the average temperature from September through November, and high precipitation in November causing delay in overall harvest. The average temperature and precipitation of 2018 fall (September through November) was 38.9 F and 3.81 inches, which were 3.7 F warmer and 0.04 inch less than the 29-year average, respectively. The harvest wrapped up in the beginning of December, with a 95% completion rate at that time.

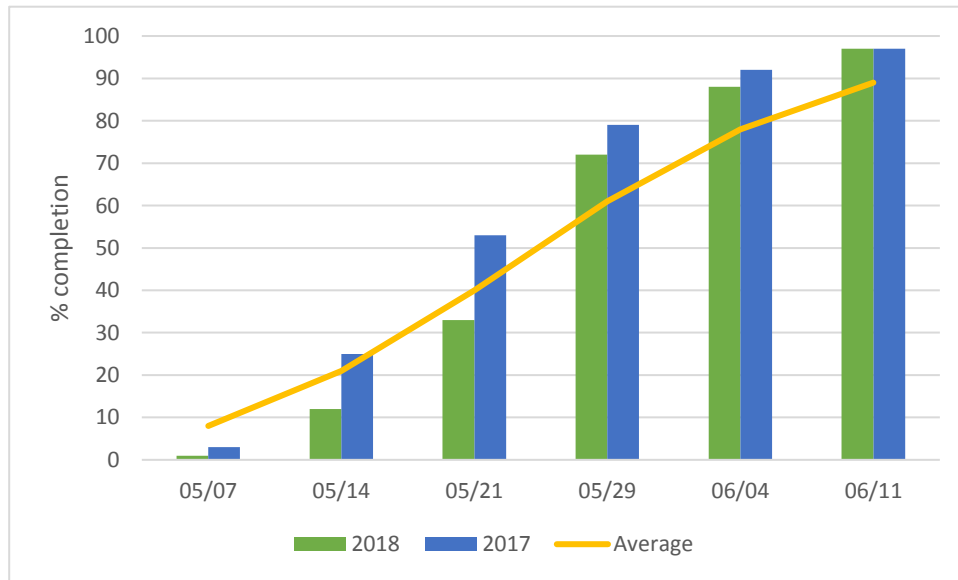


Figure 3. Planting progress of 2018 North Dakota soybeans presented by % completion

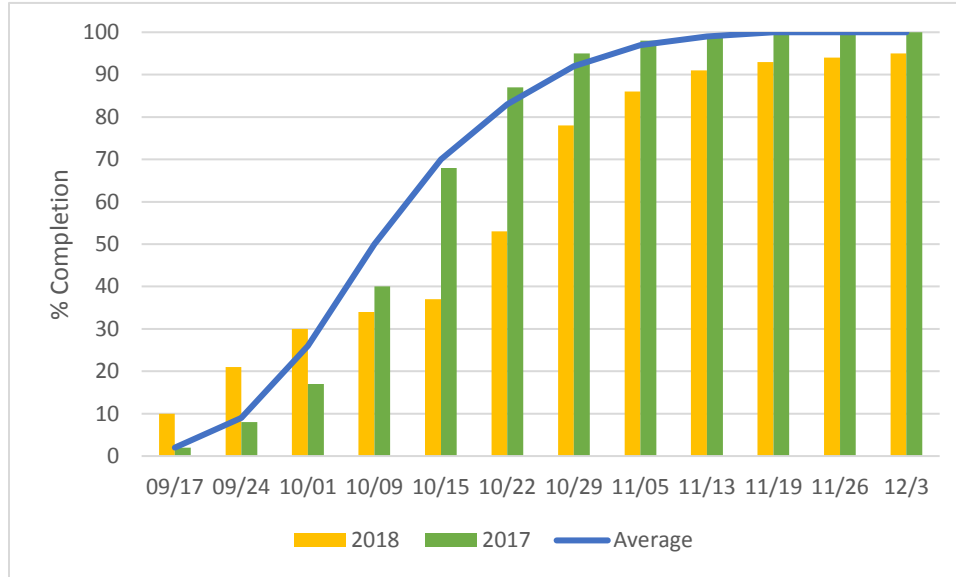


Figure 4. Harvest progress of 2018 North Dakota soybeans presented by % completion

## 2018 North Dakota Soybean Quality Results

A summary of the 2018 ND soybean quality result is presented on Table 2 with average, maximum, minimum and standard deviation (STDEV) of each parameter. It is worth noting that the initial moisture content of samples received varied greatly from a minimum of 6.7% to a maximum of 21.6% with quite a few samples above 20%.

Table 2. Summary of 2018 North Dakota soybean with average, maximum, minimum and standard deviation (STDEV)

	Average	Maximum	Minimum	STDEV
<b>Proximate</b>				
<b>Moisture (%)</b>	12.3	21.6	6.7	2.09
<b>Test weight (lb/bu)</b>	57.4	60.2	52.1	1.34
<b>Protein<sup>1</sup></b>	33.2	37.3	29.7	1.23
<b>Oil<sup>1</sup></b>	16.6	18.3	15.1	0.56
<b>Fiber<sup>2</sup></b>	7.9	8.5	7.4	0.18
<b>Ash<sup>2</sup></b>	4.9	5.3	4.6	0.12
<b>Color</b>				
<b>L*</b>	61.1	64.5	56.3	1.17
<b>a*</b>	4.2	5.4	2.7	0.54
<b>b*</b>	20.4	23.8	15.2	1.68
<b>Fatty Acid</b>				
<b>Palmitic<sup>2</sup></b>	12.2	13.1	11.5	0.32
<b>Stearic<sup>2</sup></b>	5.3	6.2	4.8	0.23
<b>Oleic<sup>2</sup></b>	22.9	32.8	17.3	2.45
<b>Linoleic<sup>2</sup></b>	57.4	63.9	48.0	2.58
<b>Linolenic<sup>2</sup></b>	9.4	11.6	7.3	0.83
<b>Soluble Sugars</b>				

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<b>Sucrose<sup>2</sup></b>	7.2	8.7	5.7	0.56
<b>Raffinose<sup>2</sup></b>	0.5	0.7	0.4	0.08
<b>Stachyose<sup>2</sup></b>	6.0	6.6	4.9	0.29
<b>Amino Acid</b>				
<b>Aspartic acid<sup>2</sup></b>	4.3	4.8	3.9	0.16
<b>Threonine<sup>2</sup></b>	1.5	1.6	1.4	0.04
<b>Serine<sup>2</sup></b>	1.8	2.0	1.7	0.06
<b>Glutamic acid<sup>2</sup></b>	6.7	7.7	6.0	0.28
<b>Proline<sup>2</sup></b>	2.0	2.3	1.9	0.06
<b>Glycine<sup>2</sup></b>	1.7	1.8	1.5	0.06
<b>Alanine<sup>2</sup></b>	1.6	1.8	1.5	0.05
<b>Cysteine<sup>2</sup></b>	0.6	0.7	0.6	0.02
<b>Valine<sup>2</sup></b>	1.8	2.0	1.6	0.06
<b>Methionine<sup>2</sup></b>	0.5	0.6	0.5	0.02
<b>Isoleucine<sup>2</sup></b>	1.8	2.0	1.6	0.06
<b>Leucine<sup>2</sup></b>	2.9	3.2	2.7	0.09
<b>Tyrosine<sup>2</sup></b>	1.4	1.6	1.3	0.04
<b>Phenylalanine<sup>2</sup></b>	2.0	2.2	1.8	0.07
<b>Lysine<sup>2</sup></b>	2.5	2.8	2.3	0.07
<b>Histidine<sup>2</sup></b>	1.0	1.1	0.9	0.03
<b>Arginine<sup>2</sup></b>	2.7	3.2	2.4	0.14
<b>Tryptophan<sup>2</sup></b>	0.4	0.5	0.4	0.02
<b><sup>1</sup>-13% moisture basis, <sup>2</sup>-percent dry matter basis</b>				

## Soybean quality results comparison by year

Comparison of soybean quality by crop year from 2009 to 2018 is presented in table 3. Average moisture of 2018 crop is 12.3%, 0.8 and 0.9 percentage points higher than the previous year and the 10-year average, respectively. Test weight is 57.4 pounds per Bu, 0.1 and 0.2 percentage points higher than the previous year and the 10-year average, respectively. Protein content is 33.2%, which is 0.3 percentage points lower than the previous year and 0.2 percentage points lower than the 10-year average. Relatively large difference is seen with oil where the 2018 average is 2.8 percentage points lower than the previous year and 1.2 percentage points lower than the 10-year average. Fatty acids in general are higher than the previous year and the 10-year average. The most notable is linoleic acid, which is 6.5 percentage points higher than the previous year and 3.6 percentage points higher than the 10-year average. Soluble sugars are higher than the previous years as well as the average. Stachyose content recorded 3.1 percentage points higher than the previous year and 1.9 percentage points increase from the 10-year average.

Table 3. Proximate, fatty acid and soluble sugar content of 2018 North Dakota soybean between 2009 and 2018 with average and standard deviation (STDEV)

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	AVG <sup>3</sup>	STDEV
<b>Proximate</b>												
<b>Moisture (%)</b>	14.6	9.8	9.7	9.2	13.2	12.7	10.6	12.3	11.5	12.3	11.6	1.7
<b>Test weight (lb/bu)</b>	55.8	57.6	57.2	57.1	56.8	57.6	57.6	57.8	57.3	57.4	57.2	0.6
<b>Protein<sup>1</sup></b>	34.9	31.4	34.6	33.2	32.9	33.7	33.4	33.7	33.5	33.2	33.4	1.0
<b>Oil<sup>1</sup></b>	19.0	18.6	18.1	18.0	18.1	16.5	17.1	16.8	19.4	16.6	17.8	1.0
<b>P + O average<sup>1</sup></b>	53.9	50.0	52.7	51.2	51.0	50.2	50.6	50.5	52.9	49.8	51.3	1.4
<b>Fiber<sup>2</sup></b>	5.2	5.7	5.1	5.6	11.4	13.7	7.0	6.9	6.4	7.9	7.5	2.9
<b>Ash<sup>2</sup></b>	5.5	4.2	5.2	5.0	5.3	5.1	5.4	5.1	5.1	4.9	5.1	0.4
<b>Fatty Acid</b>												
<b>Palmitic<sup>2</sup></b>	12.9	11.3	11.0	12.4	11.4	11.0	12.4	12.6	11.4	12.2	11.9	0.7
<b>Stearic<sup>2</sup></b>	4.7	4.1	4.9	5.0	4.6	3.8	4.3	5.3	4.7	5.3	4.7	0.5
<b>Oleic<sup>2</sup></b>	17.7	20.9	20.0	21.8	19.2	15.8	20.3	20.8	19.5	22.9	19.9	2.0
<b>Linoleic<sup>2</sup></b>	53.4	54.0	53.2	52.0	51.9	55.0	51.5	59.0	50.9	57.4	53.8	2.6
<b>Linolenic<sup>2</sup></b>	9.7	8.7	9.9	7.7	9.4	10.7	8.4	9.5	8.8	9.4	9.2	0.8
<b>Soluble sugar</b>												
<b>Sucrose<sup>2</sup></b>	4.7	6.5	6.6	5.5	6.1	7.3	6.1	6.4	6.4	7.2	6.3	0.8
<b>Raffinose<sup>2</sup></b>	0.5	0.4	0.5	0.5	0.6	0.6	0.6	0.5	0.5	0.5	0.5	0.1
<b>Stachyose<sup>2</sup></b>	4.2	4.1	5.5	1.8	5.9	3.6	2.8	4.3	2.9	6.0	4.1	1.4
<sup>1</sup> -13% moisture basis, <sup>2</sup> -percent dry matter basis <sup>3</sup> -10-year average												



## Amino Acids

Comparison of 18 amino acids between 2017 and 2018 along with 10-year average and standard deviation (STDEV) are presented in table 4. Table 8 presents amino acids by ND agricultural districts. The table 4 presents total amino acids as well as sum of 5 and 10 essential amino acids and critical amino acid value. These values can be used as an indicator of protein *quality* whereas crude protein percentage indicates protein *quantity*. Northern grown soybeans especially in the four-state-region (MN, MT, ND and SD) tend to have a favorable essential amino acid profile. Research indicates that soybeans with lower crude protein content tend to have a higher proportion of the 5 essential amino acids (5 EAA: Threonine, Cysteine, Methionine, Lysine, and Tryptophan) (Miller-Garvin and Naeve, 2018). That is not the case this year with ND soybeans. The value for 5 EAA is 15% which is 0.4 and 0.3 percentage points higher than the 2017 and 10-year average, respectively, yet crude protein content is at a record high. Critical amino acid value is the same as the previous year as well as the 10-year average.

Table 4. Amino acid contents of 2018 North Dakota soybean in 2017 and 2018 with average and standard deviation (STDEV)

	2017	2018	AVG <sup>5</sup>	STDEV
<b>Aspartic acid<sup>1</sup></b>	4.4	4.3	4.3	0.1
<b>Threonine<sup>1</sup></b>	1.5	1.5	1.5	0.2
<b>Serine<sup>1</sup></b>	1.7	1.8	1.8	0.4
<b>Glutamate<sup>1</sup></b>	6.8	6.7	6.5	0.8
<b>Proline<sup>1</sup></b>	1.9	2.0	2.0	0.2
<b>Glycine<sup>1</sup></b>	1.6	1.7	1.8	0.4
<b>Alanine<sup>1</sup></b>	1.7	1.6	1.7	0.2
<b>Cysteine<sup>1</sup></b>	0.6	0.6	0.6	0.1
<b>Valine<sup>1</sup></b>	2.0	1.8	2.0	0.2
<b>Methionine<sup>1</sup></b>	0.5	0.5	0.6	0.1
<b>Isoleucine<sup>1</sup></b>	1.9	1.8	1.9	0.1
<b>Leucine<sup>1</sup></b>	3.0	2.9	3.0	0.2
<b>Tyrosine<sup>1</sup></b>	1.7	1.4	1.5	0.1
<b>Phenylalanine<sup>1</sup></b>	2.0	2.0	2.0	0.2
<b>Lysine<sup>1</sup></b>	2.6	2.5	2.5	0.3
<b>Histidine<sup>1</sup></b>	1.0	1.0	1.0	0.1
<b>Arginine<sup>1</sup></b>	2.8	2.7	2.8	0.1
<b>Tryptophan<sup>1</sup></b>	0.3	0.4	0.4	0.1
<b>Total AA<sup>2</sup></b>	37.9	37.4	37.8	1.2
<b>5 EAA<sup>3</sup> (% of 18 AA)</b>	14.6	15.0	14.7	0.6
<b>10 EAA<sup>4</sup> (% of 18 AA)</b>	40.4	40.5	40.6	1.0
<b>Critical amino acid value</b>	4.5	4.5	4.5	0.2

<sup>1</sup>-Percent dry matter basis, <sup>2</sup>-Sum of 18AA, <sup>3</sup>-Sum of threonine, cysteine, methionine, lysine, tryptophan, <sup>4</sup>-Sum of the 5 EAA plus valine, isoleucine, leucine, phenylalanine and histidine, <sup>5</sup>-10-year average

## Protein

A summary of crude protein percentage between 2009 and 2018 along with 10-year average of the U.S. and ND soybeans is presented in Figure 5. Soybean protein content in 2018 by agricultural districts is shown in Table 5. The difference between the U.S. and the ND average is 0.7 percentage points, 0.1 percentage point higher than the previous year difference of 0.6 percentage points. Even though the protein content of 2018 ND crop is lower than the previous year, slightly higher than the average protein content at the national level may have contributed to the difference.

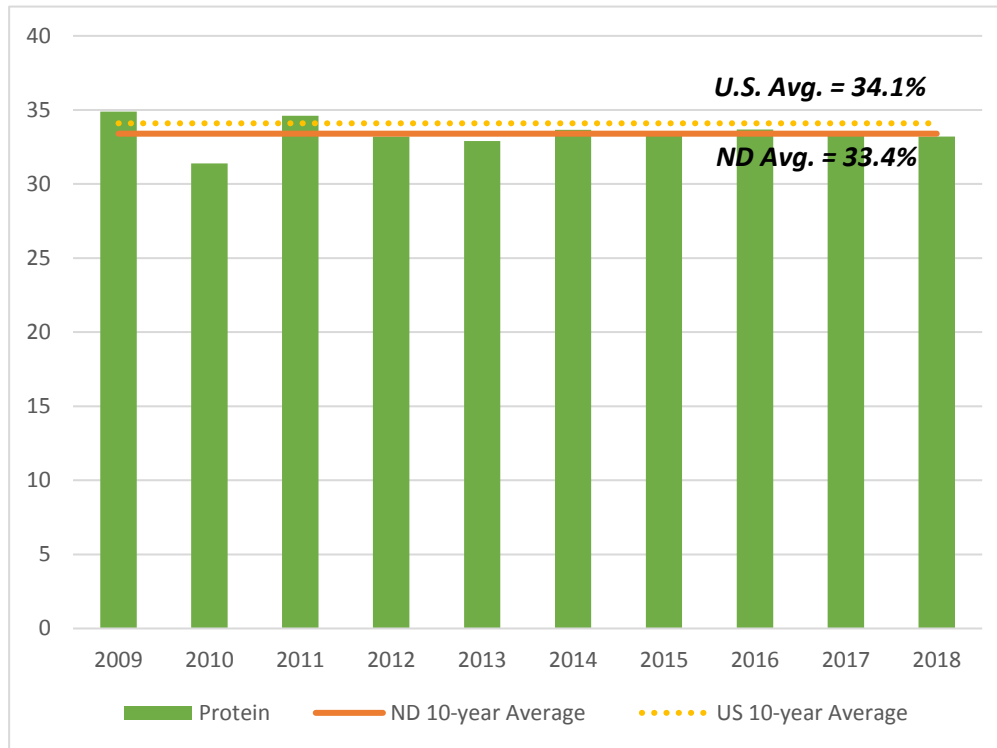


Figure 5. Percent protein (13% moisture basis) of North Dakota soybean between 2009 and 2018 and the 10-year average of ND and the U.S.

## Oil

A summary of oil percentage between 2009 and 2018 along with the 10-year average of the U.S. and ND soybeans is presented in Figure 6. Soybean oil content in 2018 by agricultural districts is shown in Table 5. The difference between the U.S. and ND average is 1.2 percentage points which is 0.1 percentage points higher than the previous year difference of 1.1 percentage points. This may have been a result of lower oil content of the 2018 ND soybeans even though the oil content of soybeans at the national level remains unchanged.

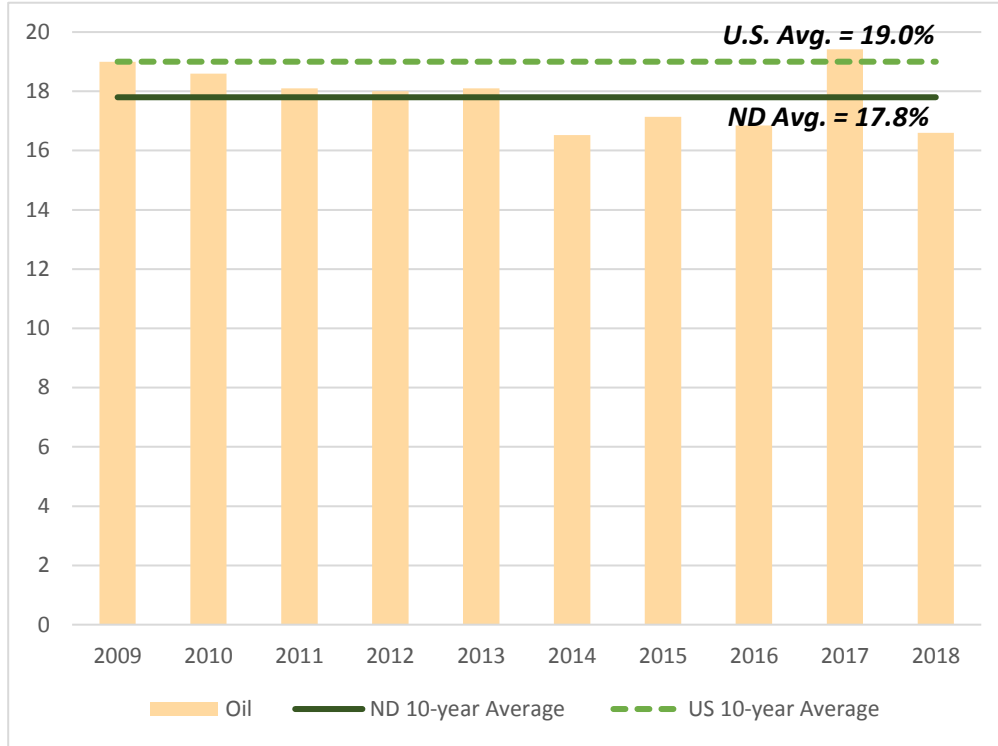


Figure 6. Percent oil (13 % moisture basis) of North Dakota soybean between 2009 and 2018 and the 10-year averages of ND and the U.S.

## Fatty acids

Comparison of fatty acid content by year is provided in Table 3, and comparison of averages by North Dakota agriculture districts is provided in Table 6. Table 3 shows the 2018 crop has the higher fatty acids content than the previous year, especially linoleic acid which is 6.5 and 3.6 percentage points higher than the 2017 and the 10-year average, respectively. Comparing across districts, a similar trend is observed. Unsaturated fatty acids (Oleic, Linoleic and Linolenic) are the major fatty acids in soybeans and there is more variation across the districts with the unsaturated fatty acids compared to the saturated fatty acids (Palmitic and Stearic).

## Soluble sugars

Comparison by year of soluble sugar content is provided in Table 3 and comparison of averages by North Dakota agriculture districts is provided in Table 7. Both sucrose and stachyose have increased yet raffinose remained the same from the previous year and the 10-year average. As previously mentioned, 2018 average of stachyose is 3.1 percentage points higher than the previous year making it the highest on the record. Comparison by districts shows sucrose values of 2018 crops ranged from 7.0% to 7.4% whereas stachyose values ranged from 5.6% to 6.1%.

## 2018 North Dakota soybean quality results by agricultural districts

A summary of proximate, fatty acids, soluble sugars and fatty acids across North Dakota agricultural districts are presented in Table 5, 6, 7, and 8, respectively.

Table 5. Proximate of 2018 North Dakota soybeans as well as 10-year average and standard deviation (STDEV) by the North Dakota agricultural districts

	District	CENT	EC	NC	NE	NW	SC	SE	WC
Protein <sup>1</sup>	2018	33.3	32.8	33.4	33.1	33.6	34.3	33.2	33.6
	Average <sup>3</sup>	33.6	33.5	33.2	33.2	33.1	32.9	33.6	33.4
	STDEV	0.8	1.0	1.3	0.9	1.1	1.4	1.1	1.5
Oil <sup>1</sup>	2018	16.4	16.7	16.6	16.7	16.3	16.3	16.7	16.5
	Average <sup>3</sup>	17.9	18.2	18.1	18.1	17.6	18.3	18.2	17.8
	STDEV	1.3	1.4	1.4	1.3	1.5	1.8	1.4	1.7
Fiber <sup>2</sup>	2018	7.9	7.9	8.1	7.9	7.9	8.0	7.9	7.9
	Average <sup>3</sup>	7.5	7.5	7.5	7.5	7.0	7.5	7.5	7.5
	STDEV	2.9	2.9	2.9	2.8	2.7	2.9	2.8	3.0
Ash <sup>2</sup>	2018	4.8	4.9	4.9	4.9	4.8	4.9	4.9	4.8
	Average <sup>3</sup>	5.1	5.1	5.0	5.1	5.0	5.1	5.1	5.1
	STDEV	0.4	0.4	0.3	0.4	0.3	0.3	0.4	0.3
<sup>1</sup> -13% moisture basis, <sup>2</sup> - Percent dry matter basis <sup>3</sup> -10-year average									

Table 6. Fatty acids of 2018 North Dakota soybeans along with 10-year average and standard deviation (STDEV) by North Dakota agricultural districts

	Districts	CENT	EC	NC	NE	NW	SC	SE	WC
Palmitic <sup>2</sup>	2018	12.2	12.3	12.3	12.5	12.2	12.2	12.1	12.2
	Average <sup>3</sup>	11.8	11.9	11.9	11.8	11.9	12.0	11.9	11.9
	STDEV	0.7	0.7	0.8	0.8	1.0	0.9	0.7	1.0
Stearic <sup>2</sup>	2018	5.3	5.3	5.5	5.4	5.5	5.5	5.2	5.5
	Average <sup>3</sup>	4.7	4.6	4.8	4.7	4.8	4.7	4.6	4.7
	STDEV	0.5	0.5	0.6	0.5	0.7	0.5	0.5	0.6
Oleic <sup>2</sup>	2018	23.1	22.1	24.4	23.4	24.2	24.3	21.5	23.6
	Average <sup>3</sup>	19.8	19.9	19.7	19.8	19.1	20.1	19.9	19.7
	STDEV	2.3	2.2	2.6	2.2	2.9	3.0	1.8	2.4
Linoleic <sup>2</sup>	2018	57.1	58.3	55.8	56.6	56.0	55.8	58.8	56.5
	Average <sup>3</sup>	53.9	53.9	53.6	53.9	54.3	53.4	54.0	53.5
	STDEV	2.7	2.9	2.5	2.8	2.2	2.3	2.8	2.4
Linolenic <sup>2</sup>	2018	9.7	9.6	8.8	9.1	9.1	9.5	9.6	9.2
	Average <sup>3</sup>	9.4	9.1	9.4	9.3	9.5	9.2	9.1	9.5
	STDEV	0.9	0.9	0.9	0.8	0.9	1.0	0.9	1.0
<sup>1</sup> -13% moisture basis, <sup>2</sup> - Percent dry matter basis <sup>3</sup> -10-year average									

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Table 7. Soluble sugar of 2018 North Dakota soybeans as well as 10-year average and standard deviation (STDEV) by North Dakota agricultural districts

	District	CENT	EC	NC	NE	NW	SC	SE	WC
Sucrose <sup>2</sup>	2018	7.3	7.2	7.1	7.1	7.4	7.0	7.1	7.2
	Average <sup>3</sup>	6.3	6.3	6.5	6.4	6.8	6.4	6.1	6.6
	STDEV	0.8	0.8	0.9	0.8	0.8	0.7	0.8	0.8
Raffinose <sup>2</sup>	2018	0.5	0.5	0.6	0.6	0.6	0.6	0.5	0.6
	Average <sup>3</sup>	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	STDEV	0.06	0.05	0.07	0.06	0.07	0.06	0.06	0.07
Stachyose <sup>2</sup>	2018	6.1	6.1	6.0	6.1	5.8	5.6	6.0	6.0
	Average <sup>3</sup>	4.3	4.2	4.4	4.3	4.2	4.3	4.3	4.3
	STDEV	1.6	1.7	1.6	1.6	1.7	1.7	1.7	1.6

<sup>1</sup>-13% moisture basis, <sup>2</sup>- Percent dry matter basis <sup>3</sup>-10-year average

Table 8. Amino acid of 2018 North Dakota soybean as well as 10-year average and standard deviation (STDEV) by North Dakota agricultural districts

Amino acid	District	CENT	EC	NC	NE	NW	SC	SE	WC
Aspartic acid <sup>2</sup>	2018	4.3	4.2	4.3	4.3	4.3	4.4	4.3	4.3
	Average <sup>3</sup>	4.3	4.3	4.3	4.3	4.2	4.2	4.3	4.3
	STDEV	0.1	0.2	0.1	0.1	0.1	0.2	0.2	0.3
Threonine <sup>2</sup>	2018	1.5	1.5	1.5	1.5	1.5	1.6	1.5	1.5
	Average <sup>3</sup>	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	STDEV	0.1	0.2	0.2	0.2	0.1	0.1	0.2	0.1
Serine <sup>2</sup>	2018	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
	Average <sup>3</sup>	1.8	1.8	1.8	1.8	1.8	1.9	1.8	1.8
	STDEV	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Glutamic acid <sup>2</sup>	2018	6.7	6.5	6.7	6.7	6.7	6.9	6.6	6.7
	Average <sup>3</sup>	6.6	6.5	6.5	6.5	6.4	6.4	6.7	6.5
	STDEV	0.8	0.8	0.8	0.8	0.7	1.1	0.2	1.1
Proline <sup>2</sup>	2018	2.0	2.0	2.0	2.0	2.1	2.1	2.0	2.1
	Average <sup>3</sup>	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	STDEV	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.1
Glycine <sup>2</sup>	2018	1.7	1.6	1.7	1.7	1.7	1.7	1.7	1.7
	Average <sup>3</sup>	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
	STDEV	0.4	0.4	0.5	0.4	0.4	0.4	0.4	0.4
Alanine <sup>2</sup>	2018	1.6	1.6	1.6	1.6	1.7	1.7	1.6	1.7
	Average <sup>3</sup>	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
	STDEV	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Cysteine <sup>2</sup>	2018	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
	Average <sup>3</sup>	0.6	0.5	0.5	0.6	0.5	0.5	0.6	0.6
	STDEV	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.2
Valine <sup>2</sup>	2018	1.8	1.8	1.8	1.8	1.8	1.9	1.8	1.8
	Average <sup>3</sup>	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	STDEV	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2



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Methionine <sup>2</sup>	2018	0.5	0.5	0.5	0.5	0.5	0.6	0.5	0.5
	Average <sup>3</sup>	0.6	0.6	0.5	0.5	0.6	0.6	0.6	0.6
	STDEV	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1
Isoleucine <sup>2</sup>	2018	1.8	1.8	1.8	1.8	1.8	1.9	1.8	1.8
	Average <sup>3</sup>	1.9	1.9	1.9	1.9	1.8	1.8	1.9	1.8
	STDEV	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Leucine <sup>2</sup>	2018	2.9	2.9	2.9	2.9	2.9	3.0	2.9	2.9
	Average <sup>3</sup>	3.0	3.0	2.9	3.0	2.9	2.9	3.0	2.9
	STDEV	0.2	0.2	0.3	0.2	0.3	0.4	0.2	0.3
Tyrosine <sup>2</sup>	2018	1.5	1.4	1.4	1.4	1.5	1.5	1.4	1.5
	Average <sup>3</sup>	1.4	1.5	1.4	1.4	1.4	1.4	1.5	1.4
	STDEV	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1
Phenylalanine <sup>2</sup>	2018	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	Average <sup>3</sup>	2.0	1.9	1.9	1.9	1.9	1.9	1.9	2.0
	STDEV	0.1	0.2	0.1	0.2	0.1	0.2	0.2	0.2
Lysine <sup>2</sup>	2018	2.5	2.5	2.5	2.5	2.5	2.6	2.5	2.6
	Average <sup>3</sup>	2.6	2.5	2.5	2.5	2.5	2.5	2.6	2.6
	STDEV	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.3
Histidine <sup>2</sup>	2018	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Average <sup>3</sup>	1.0	1.0	1.0	1.0	1.1	1.0	1.0	1.0
	STDEV	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Arginine <sup>2</sup>	2018	2.8	2.7	2.8	2.7	2.8	2.9	2.7	2.8
	Average <sup>3</sup>	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
	STDEV	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Tryptophan <sup>2</sup>	2018	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Average <sup>3</sup>	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	STDEV	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

<sup>1</sup>-13% moisture basis, <sup>2</sup>- Percent dry matter basis <sup>3</sup>-10-year average

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