Comparison of the nutritive value of soybean meal from U.S. and Brazilian soybeans

by

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ABSTRACT

What are the differences of soybean meal produced from different countries' soybeans? The U.S. soybean industry strives to differentiate U.S. soybeans in the Chinese domestic market for the livestock and aquaculture industry. More than 90% of China's soybean consumption is dependent on imported soybeans. More than 60% of U.S. soybean exports enter the Chinese market. The U.S. and Brazil are the top two soybean sellers to the Chinese market. The Brazilian soybean share in Chinese market increased in the past several years due to U.S.-China trade disputes. The U.S. soybean industry goal is to expand their sales volume in China and differentiate the U.S. soybean from those produced in other countries.

In this study twenty-three Brazil soybean meal samples and twenty-seven U.S. soybean meal samples were analyzed and the nutrient value was compared. Wet chemistry methods were used to test the major amino acids profile in soybean meal. Results showed that five amino acids from the U.S. beans are greater than Brazil, but not statistically significant. The sucrose and stachyose levels from the U.S. beans are statistically greater than Brazil. Digestibility of dry matter and crude protein from U.S. soybean meal are not statistically significantly greater than Brazilian soybean meal. The quality of U.S. origin soybean meal is greater than Brazil. With the price of 43% protein level being the same in China, soybean meal end users, livestock producers will benefit from using U.S. originated soybean meal.

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I wish to thank my husband first. In the past two years, I was talking and sharing with him at dinner time on what I learnt in the MAB class. Every time he showed curiosity listening to me and discussing with me on some point. Right now when remembering those moments, I feel warm and happy. He also gave me a lot of encouragement and support. He undertook most of family housework and accompanied the twelve-year-old boy when I was travelling to the States attending campus session in the last two years.

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CHAPTER I: INTRODUCTION

In the past five years, China annually imported over 80 million metric tons of soybeans (Table 1.1). The major factors for China importing soybeans is to satisfy animal protein needs in livestock industry. In this research, the quality and nutritive value of soybean meals from the U.S and Brazil, the two biggest exporters to China, are compared.

The soybean meal samples studied were produced in Chinese local crushing plants, using beans imported from the U.S. and Brazil. Samples were collected in 2019 from different Chinese crushing plants. The objective is to determine if the nutritive value is the same. For local soybean meal end users, they can apply precision formulation processes once they know the difference of nutritive value from soybean origins.

The U.S. and Brazil are the two biggest exporters to the Chinese soybean market. China uses about 100 million tons of soybeans per year and almost 90% of that consumption depends on imports. U.S. beans accounted for the dominant market share in China market in previous years. Since 2013, Brazil is catching up (Table 1.1). From 2009 to 2012, China bought the most soybeans from the U.S. Since 2013, Brazil has exceeded the U.S. as the number one exporting country. The first reason for this is that some buyers mentioned that the China soybean meal market is driven by price, protein and oil level. The beans from South America can produce meal with a higher protein and oil level. Secondly, in 2018 and 2019 with the trade disputes, China put retaliatory tariff on U.S. beans. This resulted in China's procurement of the most expensive soybeans in the world and the U.S. farmers' selling the cheapest soybeans during the trade war period. In 2018 and 2019, the U.S. exported to China 16.64 MMT and 17.01 MMT, decreasing about 50% compared to that in 2017. It is estimated that China's soybean consumption will increase in the future. The U.S. soybean industry wants to gain the market share in China.

Table 1.1 China Soybean Imports from 2009 to 2020 (January-December)

Year	Total Imports (tons)	Argentina (tons)	USA (tons)	Brazil (tons)	USA Share (%)	Brazil Share (%)
2009	42,545,577	3,744,190	21,805,000	15,993,400	51.25	37.59
2010	54,785,832	11,187,300	23,590,400	18,586,200	43.06	33.93
2011	52,634,084	7,838,300	22,352,900	20,621,100	42.47	39.18
2012	58,379,928	5,895,590	25,969,600	23,889,900	44.48	40.92
2013	63,404,689	6,121,600	22,264,600	31,810,600	35.12	50.17
2014	71,399,063	6,003,430	30,028,200	32,003,800	42.06	44.82
2015	81,739,736	9,437,440	28,412,300	40,126,800	34.76	49.09
2016	83,229,211	8,013,920	33,657,000	38,036,600	40.44	45.70
2017	95,527,654	6,581,040	32,851,800	50,927,400	34.39	53.31
2018	88,030,932	1,463,950	16,640,100	66,083,200	18.90	75.07
2019	88,584,582	8,791,570	17,014,600	57,676,500	19.21	65.11
2020	100,320,000	7,455,600	25,887,800	64,276,800	25.81	64.07

Data source from JCI Shanghai

In this research fifty soybean meal samples were tested for crude protein, ash, ethanol extract, crude fiber, eighteen amino acids and sugar. Protein digestibility was also tested. The objective is to determine the differences of soybean meal from different soybean origins, the U.S. and Brazil. The U.S. soybean industry continually attempts to differentiate the U.S. soybean from those origins. Any advantage for the U.S. soybean should increase exporting volume.

CHAPTER II: LITERATURE REVIEW

The chemical composition, protein quality and nutritive value of soybean meal depends on numerous factors including seed variety, environmental conditions during growing, harvesting and storage of the soybeans and the procedure used for oil extraction (Ibanez, et al. 2020). There is some research on the quality of soybean meal from different countries in Spain, New Zealand and U.S. etc. Few samples have been studied from China domestic crushing plants. As the largest soybean consumer in the world, domestic data is very meaningful for livestock producers in China.

Soybean meal is the major protein source in the pig and chicken diet used in some countries. Researchers analyzed the protein, amino acids, sugar content and energy after fed to pigs and chickens. They also compare composition and digestibility of soybean meals sourced from different countries.

Zhichuan Jason Yan (2001) conducted a research on quality variation of feed ingredients and its economic impact. He collected feed products from twenty four feed mills in China to test the moisture and protein content from 1998 to 2000. He used hypothesis tests and analysis of variance to analyze the means of the quality of feed products and ingredients. He also adopted the Taguchi Loss Function and @Risk spreadsheet simulation program to reveal the economic impact of the variability of ingredients and finished products. He found that for soybean meal, protein content differs from year to year and source to source. Soybean meal from northeast of China contains lower protein. The quality of U.S. soybean meal tends to be more consistent.

Ibanez (2020) did a meta-analytical study with 1,944 soybean meal samples from eighteen published articles including 58 comparison experiments. The nutritive value of soybean meal was compared from four major soybean producing countries: the U.S., Brazil, Argentina and India. Brazilian soybean meal had the highest crude protein level (47%) among the four countries and India had the lowest (46.3%). The difference was statistically significant. When looking at the Lysine level (% CP), the U.S. was the highest and Brazil and India were the lowest. When the soybean origin is closer to the equator, the crude protein level of the soybean meal tends to be higher. The major amino acid level as the percentage of crude protein is lower and easy to have Mallard reaction that reduces the digestibility of amino acids (Table 2.1).

Soybean meal is a major protein source and an energy provider for livestock. Coon et al. (1990) studied carbohydrate digestibility. The digestibility of sucrose is 77.7%. The U.S. meal has higher sucrose content. The energy level of USA meal is 2,146 based on CVB 2018a equation (Ibanez, et al. 2020).

Conclusions summarized from the meta analysis were that at similar crude protein content, the nutritive value of soybean meal is greater for the U.S. than for the South American or Indian meals. U.S. meal has less crude protein and fiber but more sucrose, phosphorous and indispensable amino acids per unit of protein than Brazilian meal. The differences observed in the nutritive value of soybean meal depend not only on the processing conditions at the crushing plant but also on the origin of the beans. Nutritionists should use different matrices for the nutritional value of soybean meal from different origins.

Table 2.1 Chemical Composition, (88% DM) Meta-analysis

	SBM origin				
	Argentina	**Brazil**	**USA**	**India**	**P-value**
Crude Protein （%）	45.5[c]	47.0[a]	46.4[b]	46.3[a,b]	***
Lys (% CP)	6.19[b]	6.12[c]	6.23[a]	6.12[c]	***
Met+Cys (% CP)	2.82[a,b]	2.75[b]	2.85[a]	2.67[c]	***
Sucrose （%）	6.4	5.2	7	4.2	***
Crude fiber （%）	4.32[c]	5.03[b]	3.88[d]	6.55[a]	***
NDF （%）	9.57[c]	10.8[b]	8.69[d]	13.0[a]	***
Phosphorus （%）	0.67[a]	0.62[b]	0.68[a]	0.57[c]	***

Source from (Ibanez, et al. 2020)

Lagos et al. (2017) conducted research on the chemical composition and amino acid digestibility of soybean meal produced in the U.S., China, Argentina, Brazil and India. They tested apparent digestibility and standard digestibility of amino acids in growing pigs. Results indicate that the crude protein levels from Brazil and India are greater than China, Argentina and the U.S. indispensable amino acids are the same as protein. India soybean meal has more trypsin inhibitors than other meals. Measures of ileal digestibility (ID) are used routinely as estimates of amino acid bio-availability in pig feed ingredients (Stein, et al. 2007). The apparent ileal digestibility (AID) and standard ileal digestibility (SID) of U.S. soybean meal are greater than Brazil, Argentina and India, but there is no statistical difference between that from U.S. and China. The meal from China has lower amino acids and the SID level of amino acids are less than the U.S. The SID of crude protein and amino acids are dependent on the country where the soybean meal is produced. In summary, the difference and the variability from each country should be evaluated when formulating diets for pigs (Lagos, L.V.; H.H. Stein 2017).

Research is conducted on pigs at the University of Illinois (Diego A. Lopez 2020) on digestible energy (DE) and metabolic energy (ME) in soybean meal sourced from different countries. The authors compare nutritional composition and concentration of digestible energy and metabolic energy of soybean meal from different countries. They conclude that the nutrient composition is different for soybean meals from different origins. India soybean meal has higher raffinose, neutral detergent fiber (NDF), insoluble dietary fiber and total dietary fiber than U.S., Brazil, Argentina and China. The variability in the digestibility of gross energy, digestive energy and metabolized energy are low for Argentina, Brazil, China and U.S. The energy value of Argentina is greater than the United States. The author indicated the major reason is a greater concentration of soluble dietary fiber of Argentina soybean meal. He also found soybean meal from Argentina, U.S. and Brazil has less variability than those from China and India.

Li Zhongchao et al. (2015) collected 22 soybean meal samples from local crushing plants, in which six of the samples are from China, six from the U.S., seven from Brazil and three from Argentina. These meals are fed to growing pigs. The U.S. meal has highest digestive energy and the Argentina meal has the highest metabolic energy, but there is no difference statistically.

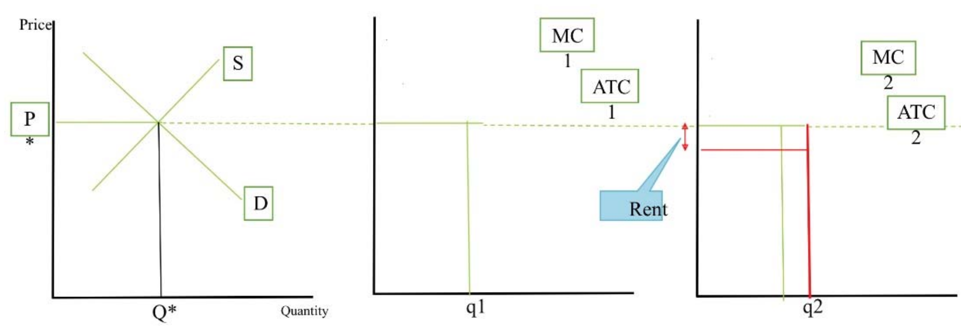
Soybean meal has been an important protein resource for pig and chicken production. Both processing conditions and soybean origin impacts the meal composition and digestibility for animals. Regarding the nutritive value of soybean meal from different origins, so far there is no consistent conclusion.

So far, little research has been conducted in China with a large number of soybean meal samples produced in local crushing plants. The soybean meal made from the U.S. soybean and Brazilian are most common in local crushing plants. In this research, the nutritive value of the soybean meal from the U.S. and Brazil is compared.

CHAPTER III: THEORETICAL MODEL

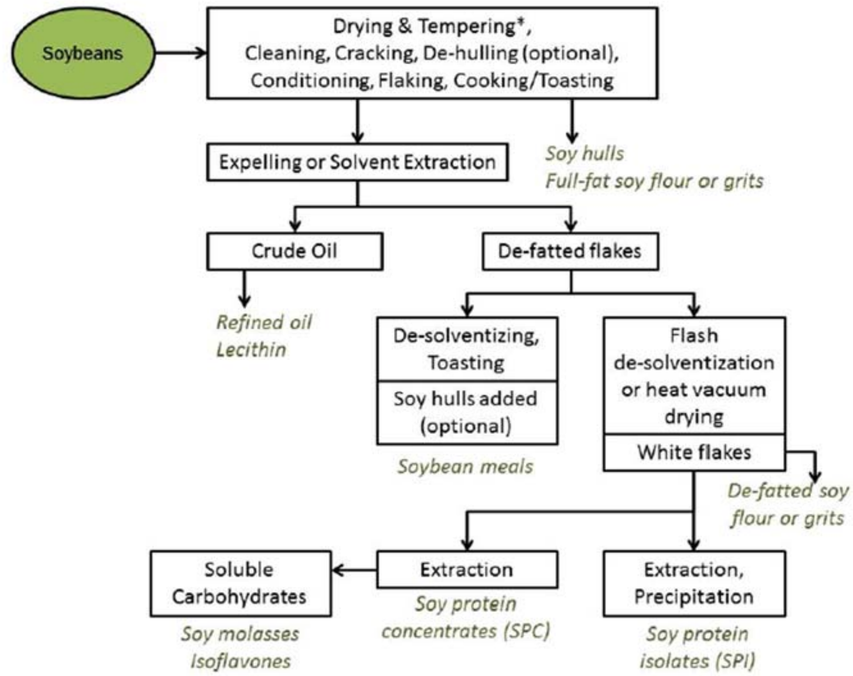
The objective of this thesis is to compare the nutritive value of soybean meal from the U.S. and Brazil. A production function is defined as, Q=F*(K, L). Q denotes the level of output produced. K and L stand for different inputs. When the quality of an input is higher, total costs would be lower or more profit would be made. The price (P) of products is determined by supply and demand (Figure 3.1). There are two products with two different average total costs (ATC 1, ATC 2) and marginal costs (MC 1, MC 2). If product 2 has lower ATC and MC, the company producing product 2 can make more money. The price difference is marked by rent in Figure 3.1.

Figure 3.1 Production Function



In this research, the nutritive value of U.S. soybean and Brazilian soybean meals are compared. They are competitors in China livestock industry as major protein resources and the market price is currently the same. The nutritive values including protein, amino acids, Ether extract, fiber, sugar and digestibility are tested and analyzed.

Figure 3.2 Schematic Representation of the Manufacturing of Soybean Products.



* only in the case of solvent extraction.
[†]Boxes with regular script are processes; boxes with italics: intermediary products; in blue and italics are final soy products.

Source: Manual of Soy Quality Analyses (U.S. Soybean Export Council)

Soybean meal is the major protein resource for pigs and chickens. It is usually regarded as a protein resource to satisfy the growth of organs and maintain the metabolism of the animal. The manufacturing method is consistent especially in large scale crushing plants in China (Figure 3.2). Protein level, amino acid percentage, energy and carbohydrate are the main variables to measure and compare nutritive value of soybean meals from the U.S. and Brazil. The protein and amino acids' levels can be tested by wet chemical method and near infrared reflectance spectroscopy (NIRS). In this study, the wet chemical method is used. Eighteen amino acids are analyzed by procedures stated in the standard protocol GB/T 18246-2000, that is based AOAC International testing method. Protein digestibility was conducted by using in vitro gastrointestinal models, that are developed by the Institute of Animal Science, Chinese Academy of Agricultural Sciences in 2009 (Patent number CN 101482460A).

3.1 Protein and Amino Acid

In China, most feed mills focus on the protein level when they purchase soybean meal from crushing plants. Actually amino acids and the digestible amino acid level are the most important factors for maintaining the growth of animals. There are two groupings of amino acids: one is essential amino acids and the other is non-essential amino acids. Regarding essential amino acids, they can't be produced by the animals and need to be added from feed ingredients. Soybean meal is regarded as one of the best natural sources of amino acids. In this study, we tested eighteen amino acids including lysine (Lys), methionine (Met), tryptophan (Trp), threonine (Thr), valine (Val), phenylalanine (Phe), leucine (Leu), isoleucine (Ile), serine (Ser), cysteine (Cys), asparagine (Asn), arginine (Arg), glutamine (Gln), alanine (Ala), glycine (Gly), histidine (His), tyrosine (Tyr), and proline (Pro).

3.2 Carbohydrates

Sucrose, stachyose and raffinose are the major three oligosaccharides in soybeans. The content was tested by methods based on GB/T 22491-2008. Sucrose is the most important because it is more digestible for pigs and chickens. Stachyose and raffinose are not easily digested by animals. After sucrose is digested, it can provide energy to animals. Ibanez (2020) shows that sucrose from soybean meal is also an energy resource. It can replace other energy ingredients when producing feed formulas. In his research, sucrose digestibility is 77.9%. So in this study, the sucrose level in soybean meals from the U.S. and Brazil is compared.

Ibanez (2020) compared the equations for estimating the energy for chickens.

WPSA(1989) $AMEn\ (kcal/kg\ DM)=3.75*CP+4.64*EE+1.49*NFE$

CVB(2018soybean) $AMEn(kcal/kgDM)=2.39*(7690-7.69*ash+6.464*CP+29.43*EE-16.09*CF)$

CVB(2018b;general) $AMEn(kcal/kg)=4.31*DigestedCrudeProtein+9.28*Digested\ EE_h+4.14*Digested(starch+sugar)$.

When estimating apparent metabolized energy (AME), the first equation WPSA (1989) considers variables including crude protein (CP), EE (Ether extract) and nitrogen-free extract (NFE). For CVB equations (2018b; general), more detailed variables are considered, e.g. digested starch, digested sugar. The metabolized energy of ingredients is different when using different equations.

3.3 Digestibility

In this study, the digestibility of dry matter and crude protein from different soybean meals are also measured by simulated pig and chicken digestion processes (Patent number for this method is 101482460). High digestibility can result in high performance and reduce nitrogen pollution to environment.

3.4 Other Criteria

In addition to the major factors above, moisture, ash, crude fat and crude fiber were also tested.

3.5 Analysis

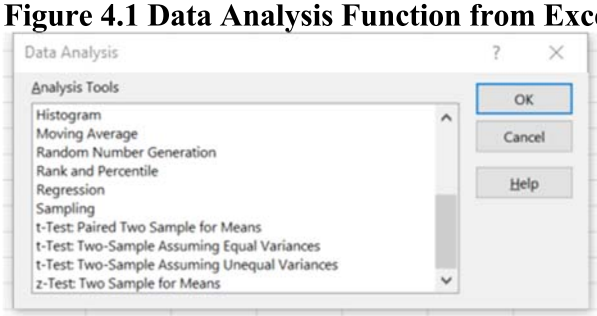
Fifty soybean meal samples were collected and analyzed. Hypothesis testing is applied to analyze the samples. The null hypothesis is the nutritive value of soybean meals from the U.S. and Brazil are the same. The alternative hypothesis is that the nutritive value of soybean meals from the U.S. and Brazil are not the same. The levels of protein, major amino acids, digestibility and carbohydrates are calculated to determine the difference between the U.S. soybean meal and Brazilian meal. The P value was calculated using a t-test (data analysis), a function of Excel (Microsoft Office 2016).

CHAPTER IV: MATHEMATICS AND DATA ANALYSIS

In China, normally there are two kinds of soybean meals categorized by the protein level, 43% (+-0.5%) and 46% (+-0.5%). In general, the price of 46% soybean meal is RMB120-150 higher than the 43% level (1% protein is priced RMB40-50). In this study fifty samples were gathered with 43% protein. Twenty-three were from Brazil and twenty-seven were from the U.S. Forty-six samples with 46% protein were also collected. Among them only five were from the U.S. and forty-one from Brazil. They are not statistically comparable. The P value was obtained by Two-sample t-Tests in Excel (2016 version).

On the top of the Data function in one sheet of Excel (2016 version), the Data and then Data Analysis tabs were used. There are three t-tests analysis tools. t-Test: Paired Two Sample for Means, t-Test: Two-Sample Assuming Equal Variances and t-Test: Two-Sample Assuming Unequal Variances (Figure 4.1).

Figure 4.1 Data Analysis Function from Excel 2016



Based on the How to do t-Tests in Excel (Jim Frost), the unequal variances version of the 2-sample t-test are suitable for the sample numbers of 23 and 27. The t-test for unequal variance is calculated by:

$$t = \frac{(\bar{x} - \bar{y}) - (\mu_x - \mu_y)}{\sqrt{\frac{s_x^2}{n_x} + \frac{s_y^2}{n_y}}}$$

where $\bar{x}$ and $\bar{y}$ are the sample means of the sample from Brazil and the U.S., respectively, n_x and n_y are the number of observations for Brazil and the U.S., respectively, and s_x^2 and s_y^2 are the sample standard deviations for Brazil and the U.S. respectively.

Samples were selected from nine provinces in nine provinces from south, east and north of China. The objective was to sample as randomly as possible. Some samples were taken from the plants near the ports, where samples were collected from the truck directly adopting "plum flower" pattern that looks like a plum flower with five points (Figure 4.2). The others were collected from bags in warehouses. Three to six bags are required for the same batch. The bags selected from high shelves, middle shelves and lower shelves. 4 kilograms of per sample was collected.

Figure 4.2 Plum Flower Pattern

4.1 Characteristics of Soybean Meal Samples

In China, soybean meal users from feed mill response is that the color of U.S. beans is golden. Brazilian soybean meal tends to be red color. Customers prefer the golden yellow color. From the samples collected, the color difference is identified. D8 and D9 (Figure 4.3) are soybean meals produced from the U.S. origin. They are light golden yellow. D73 and D74 (Figure 4.4) are from Brazil origin, whose color is more red. Some feed mills, which produce full fat soybean meal, indicate that they prefer using U.S. soybean as the color of finished products are more popular for end users.

Figure 4.3 Soybean Meal Produced by U.S. Soybean

Figure 4.4 Soybean Meals Produced by Brazilian Soybean

4.2 Protein and Amino Acid Content

Table 4.1 Average Level of Crude Protein, Ether Extract and Crude Fiber (Dry Matter Basis 0.88g DM/g)（%）

	Crude Protein	Ether extract	Crude Fibre
Brazil	0.4975	0.0120	0.0709
U.S.	0.4939	0.0124	0.0638
P value	0.1626	0.6580	0.0209

Table 4.1 measures the crude protein and ether extract. They are not statistically significantly different at the 5% level. The crude fiber from the U.S. is less than Brazil.

A total of eighteen amino acids were tested. They are Proline, Glycine, Glutamate, Tryptophan, Aspartate, Serine, Threonine, Valine, Alanine, Methionine, Isoleucine, Leucine, Histidine, Tyrosine, Phenylalanine, Lysine, Arginine, Cysteine. Results show that the levels for five amino acids from U.S. soybeans are greater than Brazil. They are Proline, Tryptophan, Methionine, Lysine, Cysteine. The sum of four critical amino acids, Lysine, Methionine, Cysteine and tyrosine from the U.S. are greater than Brazil,but not statistically significantly. Proline and tryptophan from the U.S. are statistically significantly greater than Brazil (Table 4.2).

Table 4.2 Tested Results for Major Amino Acids by Wet Chemistry Methods (% CP)

	Proline	Tryptophan	Methionine	Lysine	Cysteine	Threonine	Lysine+Methionine+ Cysteine+Threonine
Brazil	5.600	1.243	1.277	6.654	1.376	4.178	13.484
U.S.	5.889	1.310	1.283	6.730	1.405	4.169	13.587
P Value	0.003	0.000	0.785	0.408	0.118	0.871	0.510

It is well known that lysine is the first limited amino acid for pigs. Figures of 4.5 and 4.6 illustrate the distribution of the ratio of lysine versus protein in the meal from U.S. soybeans and Brazilian soybeans, respectively. The U.S. ratios are more close and consistent to the trend line, but the Brazilian points scattered widely. This is similar investigation of the research conducted in University Politecnica Madrid in Spain (2011).

Figure 4.5 Ratio of the Lysine with Protein from the U.S. Soybean

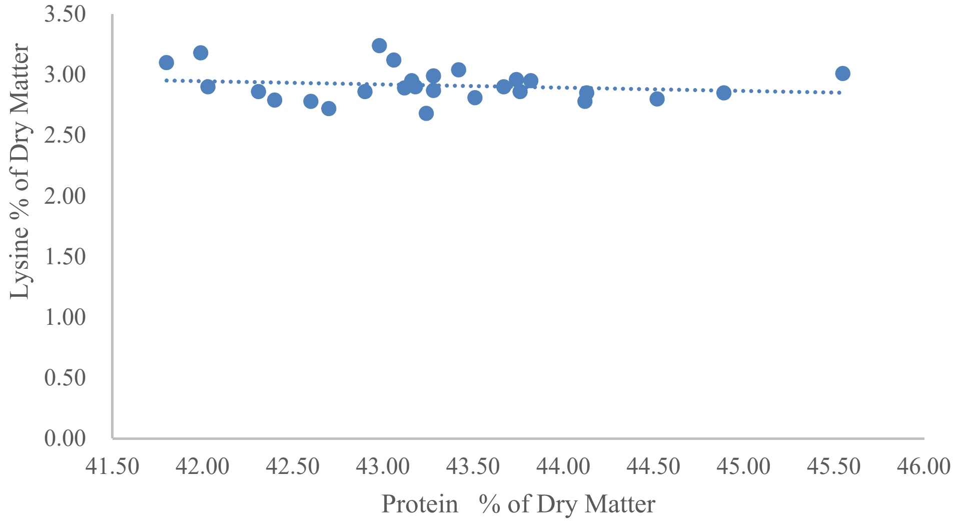
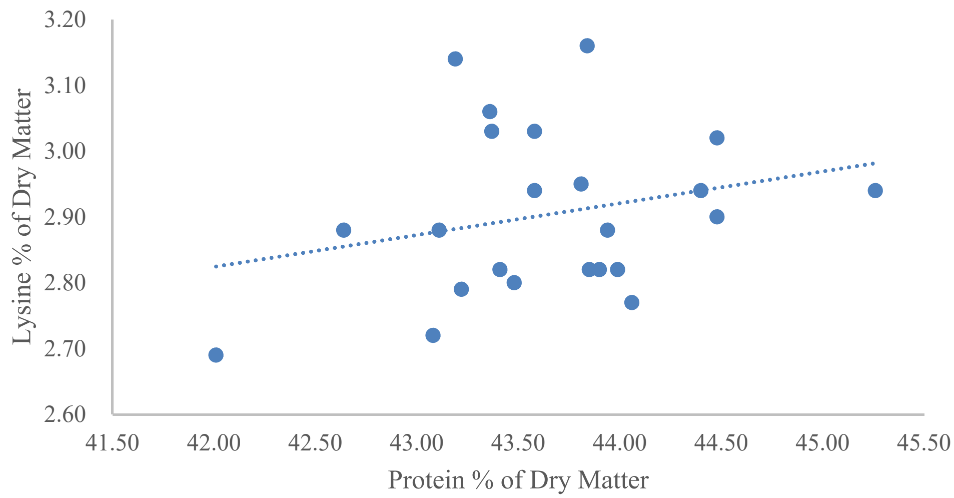


Figure 4.6 Ratio of the Lysine with Protein from Brazilian Soybean



4.2 Soybean Oligosaccharide

There are three major oligosaccharides in soybean meal. The methods in GB/T22491-2008 are adopted to test for sucrose, stachyose and raffinose content by High Performance Liquid Chromatography (HPLC). The sucrose level of U.S. soybean meal is statistically significantly greater than Brazil (Table 4.3). Stachyose from the U.S. soybean meal is greater than Brazil but not significantly. Raffinose, which is not an easily digestible sugar, from the U.S. is less than Brazil. High levels of sucrose can bring more energy to pigs and chickens. It can save energy ingredients cost.

Table 4.3 Average Content of Sucrose, Stachyose and Raffinose from the USA and Brazilian Soybean (g/kg)

	Sucrose	Stachyose	Raffinose
Brazil	50.5500	22.6100	11.1300
USA	59.9500	24.8900	9.6300
P Value	0.0001	0.1165	0.0012

4.3 Digestibility

Both dry matter and crude protein digestibility from U.S. soybean meal are greater than soybean meal from Brazilian soybeans in the pigs and chicken simulation trial (Table 4.4). Digestibility are more important for animals.

Table 4.4 Digestibility Result on Dry Matter and Crude Protein from the U.S. and Brazil （%）

	Pig		Chicken	
	Dry Matter	Crude Protein	Dry Matter	Crude Protein
Brazil	67.4500	90.4900	63.8700	86.5100
USA	69.3400	91.2800	66.9900	88.3300
P Value	0.0027	0.0065	0.0001	0.0000

4.4 Economic Analysis

A broiler least cost feed formula was determined using typical ingredients (Table 4.5). This formula was calculated by the function of Solver in Excel. Research results for crude protein, lysine, methionine, cysteine, threonine, tryptophan, isoleucine, valine, arginine, sucrose and protein digestibility in poultry were input to the function. The least cost formula resulted by Solver is the U.S. soybean meal. The total least cost is

RMB2775.8 per ton. This reduced RMB by 190.59 ($29.3 @exchange rate 6.5) if using Brazilian soybean meal (Table 4.6 Sensitivity Report).

Table 4.5 Least Cost Feed Formula for Broiler Chicken

Ingredient	BRA SBM	USA SBM	USA CORN	SOY OIL	LIME	DCP	SALT	BICARB	L Lysine	DL Meth	L Thre	Premix
Price RMB	3,300	3,300	2,000	**9,910**	300	2,600	650	1,300	13,000	16,250	15,000	6,500
Min	-	-	-	-	-	-	-	-	-	-	-	0.005
Actual	**-**	**0.363**	**0.573**	**0.032**	**0.007**	**0.015**	**0.003**	**0.002**	**0.001**	**0.003**	**0.000**	**-**
Maximum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 4.6 Sensitivity Report Comparing Brazilian Soybean Meal and U.S. Soybean Meal

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
D5	Actual BRA SBM	0	190.59268	3300	1E+30	190.592678
E5	Actual USA SBM	0.363	0	3300	197.343259	2223.49895
F5	Actual USA CORN	0.573	0	2000	1800.29432	1E+30
G5	Actual SOY OIL	0.032	0	9910	1E+30	5611.4068
H5	Actual LIME	0.007	0	300	5789.49224	4060.86447
I5	Actual DCP	0.015	0	2600	180713.382	3739.5611
J5	Actual SALT	0.003	0	650	3280.41052	1337689.07
K5	Actual BICARB	0.002	0	1300	958267.163	2157.90776
L5	Actual L Lysine	0.001	0	13000	72451.132	16916.0999
M5	Actual DL Meth	0.003	0	16250	367805.667	19954.1973
N5	Actual L Thre	0.000	0	15000	182139.069	18777.6572
O5	Actual Premix	0	10249.2874	6500	1E+30	10249.2874

4.5 Summary

With the development of the economic situation in China, meat consumption has increased greatly in last thirty years. The livestock industry is expanding. Soybean is the major protein source for pigs and chickens. The U.S. and Brazil are the two biggest competitors in the Chinese domestic soybean market. Soybeans from Brazil are growing in market share. The U.S. soybean industry is trying to differentiate the quality of U.S. origin soybeans to China.

In this research, fifty soybean meal samples are collected from nine crushing plants in China. Twenty-three soybean meals are from Brazilian soybeans and twenty-seven meals are from U.S. soybeans.

Major nutritive values are tested including protein and major amino acid profile, oligosaccharides and digestibility of dry matter and protein in pigs and chickens.
Crude protein was tested by the Kjeldahl method (GB/T 6432-2018). The nitrogen level is acquired and then multiplied by 6.25 times. The result is an estimate of the crude protein percentage in soybean meal. The amino acids are tested based on wet chemistry methods (GB/T 18246-2000). Hydrochloric acid hydrolysis is employed and followed by ion exchange chromatography. Soybean oligosaccharide including sucrose, stachyose and raffinose were tested by High Performance Liquid Chromatography (HPLC).

Results show that the major amino acids, methionine, lysine, cysteine and the sum of lysine, methionine, cysteine and threonine from U.S. soybeans are greater than Brazil, though not statistically significantly. Major soybean oligosaccharides, the sucrose levels from the U.S. are statistically significantly greater than Brazil. The digestibility of dry matter and crude protein from the U.S. are significantly greater than Brazil. The digestibility of dry matter and crude protein play a key role for growing pigs and chickens. They will bring greater profit for producers.

In summary, in this research, it is demonstrated that the U.S. soybean has advantages in key amino acids profiles, energy level and digestibility of crude protein. In China, the market price of the two soybean meals is the same. When local feed millers input the different nutrient level to feed formula software or an Excel file, for broilers they can benefit from the U.S. soybean meal and reduce production cost ($29/ton for broiler complete feed).

CHAPTER V: CONCLUSIONS

The nutritive value of soybean meal is influenced by production process and soybean origin (Ibanez, et al. 2020). With the development of crushing plants, processing technologies are close to be standardized and are more consistent. Different origins of soybeans play an important role on determining the quality of soybean meal. Results of this research indicates that China local manufactured soybean meal from U.S. soybeans have higher digestibility of major amino acids (Lysine, Methionine, Cysteine and Threonine), higher sucrose level with more energy and better digestibility for dry matter and crude protein in chicken and pigs than those from Brazil.

The implication of the results is that when the U.S. soybean industry communicates with soybean buyers and end users in China, local data and analyses demonstrate the difference. This demonstration may help feed millers and livestock producers optimize feed formulas and produce precision nutrition for pigs and broilers at a lower cost.

The shortcoming of the research is that the soybean hull might be added to the samples more or less to adjust protein level in some crushing plants. This will influence the correction of crude fiber content. It is difficult to compare with “meta analytical study” (Ibanez, et al. 2020) . For the meta-analytical study, they compared de-hulled soybean meal. In their study, for protein level, soybean meal from Brazil are statistically significantly greater than the U.S. soybean meal. Lysine content (as protein percent) from the U.S. soybean meal are statistically significantly greater than Brazilian soybean meal.

The U.S. soybean industry will continue to conduct research in different countries in the world to differentiate the U.S. soybean. In the future, in China, more soybean meal samples need to be collected from different areas. China needs to deeply understand the characteristics and advantages from different soybean origins.

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APPENDIX A

Sample Number	Sample Label	Category	Province	facturer batch nu	Country origin	Factory for collecting samples
1	D4	SBM43	COFCO (Dongguan) Grain and Oil Industry Co., Ltd.	190503061	United States	COFCO Feed (Foshan) Co., Ltd.
2	D5	SBM43	›ngguan Fuzhiyuan Feed Protein Development Co., L	190513031	Brazil	COFCO Feed (Foshan) Co., Ltd.
3	D6	SBM43	COFCO (Dongguan) Grain and Oil Industry Co., Ltd.	190521101	United States	COFCO Feed (Foshan) Co., Ltd.
4	D7	SBM43	China Storage Grain (Dongguan) Oil Industry Co., Ltd	190523021	United States	COFCO Feed (Foshan) Co., Ltd.
5	D8	SBM43	COFCO (Dongguan) Grain and Oil Industry Co., Ltd.	190522051	United States	COFCO Feed (Foshan) Co., Ltd.
6	D9	SBM43	China Tex Corporation	20190427	United States	COFCO Feed (Chengdu) Co., Ltd.
7	D10	SBM43	Sinograin oils corporation(Chengdu)	20190509	United States	COFCO Feed (Chengdu) Co., Ltd.
8	D11	SBM43	Sinograin oils corporation(Chengdu)	20190519	United States	COFCO Feed (Chengdu) Co., Ltd.
9	D15	SBM43	:O Donghai Grain and Oil Industry (Zhangjiagang) Co	20190513	United States	COFCO Feed (Dongtai) Co., Ltd.
10	D17	SBM43	COFCO Excel Joy(Tianjin)Co.,Ltd.	20190527	United States	COFCO （Beijing）Feed Sci&Tech Co., Ltd.
11	D18	SBM43	COFCO Excel Joy(Tianjin)Co.,Ltd.	20190528	United States	COFCO （Beijing）Feed Sci&Tech Co., Ltd.
12	D23	SBM43	Sanhe HuiFu grain and oil group feed protein Co., Ltd	20190618	United States	COFCO Feed (Tangshan) Co., Ltd.
13	D24	SBM43	Bunge Zhengda (Tianjin) grain and Oil Co., Ltd.	20190613	Brazil	COFCO Feed (Tangshan) Co., Ltd.
14	D25	SBM43	COFCO Grain and oil industry (Huanggang) Co., Ltd.	20190617	Brazil	COFCO Feed (Huanggang) Co., Ltd.
15	D26	SBM43	COFCO Grain and oil industry (Huanggang) Co., Ltd.	20190619	Brazil	COFCO Feed (Huanggang) Co., Ltd.
16	D33	SBM43	COFCO Grain and oil industry (Jingzhou) Co., Ltd.	20190510	United States	COFCO Feed (Jingzhou) Co., Ltd.
17	D34	SBM43	COFCO Grain and oil industry (Jingzhou) Co., Ltd.	20190511	United States	COFCO Feed (Jingzhou) Co., Ltd.
18	D35	SBM43	COFCO Grain and oil industry (Jingzhou) Co., Ltd.	20190512	United States	COFCO Feed (Jingzhou) Co., Ltd.
19	D37	SBM43	Bunge (Nanjing) grain and Oil Co., Ltd.	20190605	Brazil	COFCO Feed (Chengdu) Co., Ltd.
20	D38	SBM43	Guangxi Huiyu grain and oil industry Co., Ltd	20190607	Brazil	COFCO Feed (Chengdu) Co., Ltd.
21	D39	SBM43	Sinograin Oils Corporation	20190619	United States	COFCO Feed (Chengdu) Co., Ltd.
22	D50	SBM43	Sinograin oil industry Dongguan Co., Ltd	20190624	United States	COFCO Feed (Foshan) Co., Ltd.
23	D51	SBM43	COFCO (Dongguan) grain and oil industry Co., Ltd.	20190620	United States	COFCO Feed (Foshan) Co., Ltd.
24	D52	SBM43	Dongguan Cargill feed protein Technology Co., Ltd.	20190624	Brazil	COFCO Feed (Foshan) Co., Ltd.
25	D56	SBM43	COFCO (Dongguan) Grain and Oil Industry Co., Ltd.	20190722	United States	COFCO Feed (Foshan) Co., Ltd.
26	D57	SBM43	COFCO (Dongguan) Grain and Oil Industry Co., Ltd.	20190722	United States	COFCO Feed (Foshan) Co., Ltd.
27	D58	SBM43	COFCO (Dongguan) Grain and Oil Industry Co., Ltd.	20190723	United States	COFCO Feed (Foshan) Co., Ltd.
28	D59	SBM43	Sinograin Oils Corporation	20190720	United States	COFCO Feed (Foshan) Co., Ltd.
29	D62	SBM43	Zhanjiang Bohai Agricultural Development Co., Ltd	20190718	Brazil	COFCO Feed (Maoming) Co., Ltd.
30	D63	SBM43	Zhanjiang Bohai Agricultural Development Co., Ltd	20190720	Brazil	COFCO Feed (Maoming) Co., Ltd.
31	D64	SBM43	China Textile grain and oil (Zhanjiang) Co., Ltd	20190727	Brazil	COFCO Feed (Maoming) Co., Ltd.
32	D65	SBM43	China Textile grain and oil (Zhanjiang) Co., Ltd	20190724	Brazil	COFCO Feed (Maoming) Co., Ltd.
33	D69	SBM43	COFCO Grain and oil industry (Chaohu) Co., Ltd	20190628	United States	COFCO Feed (Chaohu) Co., Ltd.
34	D70	SBM43	Hebei Jiahao grain and Oil Co., Ltd.	20190716	Brazil	COFCO Feed (Tangshan) Co., Ltd.
35	D71	SBM43	Qinhuangdao Jinhai grain and oil industry Co., Ltd	2019072406E	Brazil	COFCO Feed (Tangshan) Co., Ltd.
36	D73	SBM43	COFCO Grain and oil (Jingzhou) Co., Ltd	20190817	Brazil	COFCO Feed (Jingzhou) Co., Ltd.
37	D74	SBM43	COFCO Grain and oil (Jingzhou) Co., Ltd	20190824	Brazil	COFCO Feed (Jingzhou) Co., Ltd.
38	D75	SBM43	COFCO Grain and oil (Jingzhou) Co., Ltd	20190828	Brazil	COFCO Feed (Jingzhou) Co., Ltd.
39	D76	SBM43	COFCO Excel Joy(Tianjin)Co.,Ltd.	20190825	Brazil	COFCO Feed (Tangshan) Co., Ltd.
40	D77	SBM43	COFCO Excel Joy(Tianjin)Co.,Ltd.	20190808	Brazil	COFCO Feed (Tangshan) Co., Ltd.
41	D82	SBM43	COFCO Grain and oil industry (Huanggang) Co., Ltd	20190731	United States	COFCO Feed (Huanggang) Co., Ltd.
42	D83	SBM43	COFCO Grain and oil industry (Huanggang) Co., Ltd	20190831	Brazil	COFCO Feed (Huanggang) Co., Ltd.
43	D84	SBM43	COFCO Grain and oil industry (Huanggang) Co., Ltd	20190902	Brazil	COFCO Feed (Huanggang) Co., Ltd.
44	D90	SBM43	Hebei Jiahao grain and Oil Co., Ltd.	20190814	Brazil	OFCO feed (Maoming) Co., Ltd. Hohhot Bran
45	D91	SBM43	COFCO Excel Joy(Tianjin)Co.,Ltd.	20190822	Brazil	OFCO feed (Maoming) Co., Ltd. Hohhot Bran
46	D92	SBM43	Louis Dreyfus Company	20190821	Brazil	OFCO feed (Maoming) Co., Ltd. Hohhot Bran
47	D93	SBM43	Sinograin Oils Corporation	20190806	United States	COFCO Feed (Chengdu) Co., Ltd.
48	D94	SBM43	Sinograin Oils Corporation	20190814	United States	COFCO Feed (Chengdu) Co., Ltd.
49	D95	SBM43	Sinograin Oils Corporation	20190822	United States	COFCO Feed (Chengdu) Co., Ltd.
50	D98	SBM43	Sinograin Oils Corporation	20190830	United States	COFCO Feed (Chengdu) Co., Ltd.

APPENDIX B

NO.	Color	Shape	Granularity	Odors	Impurity	Mold	Insect
D4	light yellow	Irregular granular	72% passed 8 mess 25% passed 20 mess	Normal bean scent	Have some pods, straw	None	None
D5	light brown	Irregular granular	87% passed 8 mess 33% passed 20 mess	Rich bean scent	Have fewer pods, straw	None	None
D6	light brown	Irregular granular	85% passed 8 mess 38% passed 20 mess	Normal bean scent	Have a few pods, straw	None	None
D7	Reddish-brown	Irregular granular	82% passed 8 mess 35% passed 20 mess	Rich bean scent	Have fewer pods, straw	None	None
D8	light brown	Irregular granular	82% passed 8 mess 30% passed 20 mess	Normal bean scent	Have fewer pods, straw	None	None
D9	light brown	Irregular granular	93% passed 8 mess 45% passed 20 mess	Normal bean scent	Have fewer pods, straw	None	None
D10	light yellow	Irregular granular	89% passed 8 mess 38% passed 20 mess	Normal bean scent	Have fewer pods, straw	None	None
D11	light yellow	Irregular granular	90% passed 8 mess 37% passed 20 mess	Normal bean scent	Have few pods, straw	None	None
D15	light brown	Irregular granular	96% passed 8 mess 43% passed 20 mess	Normal bean scent	Have few pods, straw	None	None
D17	light brown	Irregular granular	90% passed 8 mess 38% passed 20 mess	Rich bean scent	Have few pods, straw	None	None
D18	light brown	Irregular granular	82% passed 8 mess 30% passed 20 mess	Normal bean scent	Have a few pods, straw	None	None
D23	light brown	Irregular granular	89% passed 8 mess， 33% passed 20 mess	Normal bean scent	Have some pods, straw	None	None
D24	Reddish-brown	Irregular granular	93% passed 8 mess， 39% passed 20 mess	Normal bean scent	Have some pods, straw	None	None
D25	light brown	Irregular granular	97% passed 8 mess， 41% passed 20 mess	Normal bean scent	Have fewer pods, straw	None	None
D26	light brown	Irregular granular	90% passed 8 mess， 24% passed 20 mess	Normal bean scent	Have some pods, straw	None	None
D33	light yellow	Irregular granular	99% passed 8 mess, 55% passed 20 mess	Less bean scent	Have few pods, straw	None	None
D34	light yellow	Irregular granular	99% passed 8 mess, 53% passed 20 mess	Less bean scent	Have few pods, straw	None	None
D35	light yellow	Irregular granular	99% passed 8 mess, 62% passed 20 mess	Less bean scent	Have few pods, straw	None	None
D37	light brown	Irregular granular	96% passed 8 mess, 47% passed 20 mess	Normal bean scent	Have a few pods, straw	None	None
D38	Reddish-brown	Irregular granular	97% passed 8 mess, 49% passed 20 mess	Normal bean scent	Have fewer pods, straw	None	None
D39	light yellow	Irregular granular	96% passed 8 mess, 52% passed 20 mess	Less bean scent	Have fewer pods, straw	None	None
D50	light brown	Irregular granular	93% passed 8 mess, 37% passed 20 mess	Less bean scent	Have few pods, straw	None	None
D51	light brown	Irregular granular	93% passed 8 mess, 23% passed 20 mess	Less bean scent	Have fewer pods, straw	None	None
D52	light brown	Irregular granular	86% passed 8 mess, 24% passed 20 mess	Less bean scent	Have some pods, straw	None	None
D56	light yellow	Irregular granular	87% passed 8 mess, 29% passed 20 mess	Normal bean scent	Have few pods, straw	None	None
D57	light yellow	Irregular granular	87% passed 8 mess, 28% passed 20 mess	Normal bean scent	Have fewer pods, straw	None	None
D58	light yellow	Irregular granular	89% passed 8 mess, 32% passed 20 mess	Normal bean scent	Have few pods, straw	None	None
D59	light yellow	Irregular granular	78% passed 8 mess, 19% passed 20 mess	Less bean scent	Have a few pods, straw	None	None
D62	light brown	Irregular granular	86% passed 8 mess, 33% passed 20 mess	Less bean scent	Have fewer pods, straw	None	None
D63	light brown	Irregular granular	90% passed 8 mess, 37% passed 20 mess	Less bean scent	Have fewer pods, straw	None	None
D64	light yellow	Irregular granular	89% passed 8 mess, 31% passed 20 mess	Normal bean scent	Have fewer pods, straw	None	None
D65	light brown	Irregular granular	93% passed 8 mess, 36% passed 20 mess	Less bean scent	Have fewer pods, straw	None	None
D69	light yellow	Irregular granular	94% passed 8 mess, 21% passed 20 mess	Normal bean scent	Have fewer pods, straw	None	None
D70	light brown	Irregular granular	92% passed 8 mess, 34% passed 20 mess	Normal bean scent	Have a few pods, straw	None	None
D71	light yellow	Irregular granular	92% passed 8 mess, 33% passed 20 mess	Normal bean scent	Have a few pods, straw	None	None
D73	light yellow	Irregular granular	91% passed 8 mess, 43% passed 20 mess	Rich bean scent	Have a few pods, straw	None	None
D74	light yellow	Irregular granular	94% passed 8 mess, 46% passed 20 mess	Rich bean scent	Have a few pods, straw	None	None
D75	light yellow	Irregular granular	93% passed 8 mess, 47% passed 20 mess	Normal bean scent	Have few pods, straw	None	None
D76	light brown	Irregular granular	92% passed 8 mess, 39% passed 20 mess	Less bean scent	Have few pods, straw	None	None
D77	light brown	Irregular granular	93% passed 8 mess, 30% passed 20 mess	Less bean scent	Have a few pods, straw	None	None
D82	light yellow	Irregular granular	92% passed 8 mess, 27% passed 20 mess	Less bean scent	Have a few pods, straw	None	None
D83	light yellow	Irregular granular	96% passed 8 mess, 48% passed 20 mess	Less bean scent	Have a few pods, straw	None	None
D84	light yellow	Irregular granular	93% passed 8 mess, 31% passed 20 mess	Normal bean scent	Have a few pods, straw	None	None
D90	light brown	Irregular granular	92% passed 8 mess, 33% passed 20 mess	Normal bean scent	Have fewer pods, straw	None	None
D91	light brown	Irregular granular	91% passed 8 mess, 39% passed 20 mess	Less bean scent	Have a few pods, straw	None	None
D92	light brown	Irregular granular	88% passed 8 mess, 29% passed 20 mess	Normal bean scent	Have a few pods, straw	None	None
D93	light yellow	Irregular granular	95% passed 8 mess, 49% passed 20 mess	Normal bean scent	Have few pods, straw	None	None
D94	light yellow	Irregular granular	95% passed 8 mess, 50% passed 20 mess	Normal bean scent	Have a few pods, straw	None	None
D95	light yellow	Irregular granular	94% passed 8 mess, 38% passed 20 mess	Normal bean scent	Have a few pods, straw	None	None
D98	light yellow	Irregular granular	95% passed 8 mess, 50% passed 20 mess	Normal bean scent	Have a few pods, straw	None	None