Kansas Agricultural Experiment Station Research Reports

Volume 10
Issue 6 *Swine Day*

Article 36

2024

An Industry Survey of the Composition and Variability of Soybean Gums and Soapstocks Across US Soybean Processing Plants

Katelyn N. Gaffield
Kansas State University, gaffield@k-state.edu

Robert D. Goodband
Kansas State University, goodband@k-state.edu

Joel M. DeRouchey
Kansas State University, jderouch@k-state.edu

See next page for additional authors

Recommended Citation

Gaffield, Katelyn N.; Goodband, Robert D.; DeRouchey, Joel M.; Tokach, Mike D.; Woodworth, Jason C.; Denny, Gordon; Smolen, Paul; Slipher, Carmen; Krishnan, Hari B.; and Gebhardt, Jordan T. (2024) "An Industry Survey of the Composition and Variability of Soybean Gums and Soapstocks Across US Soybean Processing Plants," *Kansas Agricultural Experiment Station Research Reports*: Vol. 10: Iss. 6. https://doi.org/10.4148/2378-5977.8651

An Industry Survey of the Composition and Variability of Soybean Gums and Soapstocks Across US Soybean Processing Plants

Funding Source

The authors appreciate the United Soybean Board for their financial support of this trial.

Authors

Katelyn N. Gaffield, Robert D. Goodband, Joel M. DeRouchey, Mike D. Tokach, Jason C. Woodworth, Gordon Denny, Paul Smolen, Carmen Slipher, Hari B. Krishnan, and Jordan T. Gebhardt

An Industry Survey of the Composition and Variability of Soybean Gums and Soapstocks Across US Soybean Processing Plants[1]

Katelyn N. Gaffield, Robert D. Goodband, Joel M. DeRouchey, Mike D. Tokach, Jason C. Woodworth, Gordon Denny,[2] Paul Smolen,[3] Carmen Slipher,[4] Hari B. Krishnan,[5] and Jordan T. Gebhardt[6]

Summary

Depending on the soybean processing plant, gums and soapstocks may be added back to soybean meal during soybean processing. Despite the potential effects on soybean meal quality, there is limited information on the composition and variation in soybean by-products and the resulting soybean meal if by-products are added back during processing. A total of 36 soybean by-product samples from 14 plants across eight different companies were used in an industry survey evaluating the composition and variation of soybean gums and soapstocks across the US. All soybean processing plants within the study produced at least one of the two by-products: soybean gums or soybean soapstocks. Soybean by-product and soybean meal samples were collected at two different timepoints: May to July 2023 and October to November 2023. The individual plants surveyed constitute approximately 30% of total US soybean meal production, with the eight participating companies representing 80% of the total US soybean meal production. By-products were analyzed for lipid quality criteria including moisture, fat by acid hydrolysis, fatty acid analysis, and oxidation markers. Furthermore, soybean meal samples were submitted for analysis of proximate composition, neutral detergent fiber, Ca, P, and trypsin inhibitor activity. Soybean gums had a greater ($P \leq 0.05$) percentage of acid hydrolyzed fat and p-Anisidine value compared to soybean soapstocks. Soybean soapstocks tended to have a greater ($P = 0.085$) percentage of moisture and volatile matter, as well as an increased ($P = 0.052$) concentration of insoluble impurities compared with soybean gums. Most notably, there was considerable variation in the composition of by-product samples between processing plants indicating differences in processing procedures or incoming soybean quality. Soybean meal containing added soybean by-products had 61% greater ($P < 0.05$) ether extract than soybean meal samples not containing added soybean by-products on a dry matter basis, but there was no difference ($P < 0.10$) in crude protein. Furthermore, trypsin inhibitor

[1] The authors appreciate the United Soybean Board for their financial support of this trial.
[2] Gordon Denny, LLC, Thornton, CO.
[3] Agri Networks Management, Old Saybrook, CT USA 06475
[4] Bunge North America, Chesterfield, MO.
[5] Agricultural Research Service, U.S. Department of Agriculture and Divisions of Plant Sciences and Animal Sciences, University of Missouri, Columbia, MO.
[6] Department of Diagnostic Medicine/Pathobiology, College of Veterinary Medicine, Kansas State University.

activity varied considerably between plants with values ranging from 1.45 to 9.26 TIU/mg of seed powder, regardless of by-product inclusion. These results provide information on the composition and variation in soybean by-products across various processing plants; however, further information is still needed to evaluate their subsequent effects on livestock diets.

Introduction

Depending on the processing plant, soybean gums and soapstocks may be added back during soybean meal production. Despite the potential impact on soybean meal quality, there is a current lack of understanding on the composition and variation in soybean by-products. Soybean gums are produced through the degumming step of oil refining in an effort to remove phosphatides from the oil, while soybean soapstocks are produced during caustic refining, which removes any remaining phosphatides and neutralizes free fatty acids. If added back to soybean meal during processing, these by-products will be transferred to the desolventizing, toasting, drying, and cooling step of production to be dried along with the soybean meal. These by-products have been suggested to contain approximately 35% crude oil.[7,8] Therefore, it is intuitive to believe adding these by-products back to soybean meal may have an impact on its quality.

The challenge with understanding how gums and soapstocks will affect soybean meal quality is the current limited information on the composition of the soybean by-products themselves. Multiple factors can affect the composition of soybean by-products including initial soybean quality, differences in degumming processes, differences in caustic refining, efficiency and age of machinery, and management. Therefore, the composition of by-products likely varies across soybean processing plants. However, there are currently no studies quantifying this variation. Therefore, the objective of this study was to investigate the composition and variability of soybean gums and soapstocks across US soybean processing plants and its impacts on subsequent soybean meal quality through an industry survey.

Procedures

A total of 36 soybean by-product samples from 14 soybean processing plants across eight different companies were used in the industry survey. The individual plants surveyed constitute approximately 30% of total US soybean meal production, while the eight participating companies represent 80% of the total US soybean meal production. All soybean processing plants within the study produced at least one of the two by-products: soybean gums or soybean soapstocks. Soybean by-product and soybean meal samples were collected at two different timepoints within the survey: May to July 2023 and October to November 2023. A total of 36 by-products samples were collected throughout the survey. By-product samples included 12 soybean gum and six soybean soapstock samples at each timepoint. Furthermore, a total of 26 soybean meal samples were collected with seven soybean meal samples containing added by-products and six samples not containing added by-products at both sample collections. It is important to note that two plants within the survey only have samples represented at one timepoint, as samples were not received by the deadlines set for this study.

---

[7] Erickson, D. R. 1995. Degumming and lecithin processing and utilization. In: D. R. Erickson, editor, Practical handbook of soybean processing and utilization. Urbana, IL. p. 174-183.
[8] Erickson, D. R. 1995. Neutralization. In: D. R. Erickson, editor, Practical handbook of soybean processing and utilization. Urbana, IL. p. 184-202.

Plants received six, 500 mL bottles (three bottles for each by-product; Nalgene lab quality amber HDPE bottles, Thermo Scientific, Waltham, MA) and two 207 mL sampling bags (Whirl-Pak, Nasco, Ft. Atkinson, WI). Upon receipt of the sampling packages, an employee from each soybean plant collected the by-product samples applicable to their production system (soybean gums and/or soapstocks). Simultaneously, a soybean meal sample was collected from each plant. Information regarding the date of collection, employee name and contact information, and if soybean processing by-products had been added back to soybean meal during the time of collection were recorded. Once collected, samples were immediately shipped overnight to Kansas State University to be prepared for analysis. All samples were stored at 39°F (4°C) until analysis was performed.

Chemical analysis

Samples of soybean gums and soapstocks were submitted for lipid quality analysis (Table 1). Each by-product sample was homogenized at the laboratory prior to being analyzed. At both timepoints, the following criteria were measured in duplicate: moisture and volatile matter by hot plate (Method Ca 2b-38; AOCS, 2017 and Method Ba 2a-38; AOCS, 2022), insoluble impurities (Method Ca 3a-46; AOCS, 2021), unsaponifiable matter (Method Ca 6a-40; AOCS, 2017), P (Methods 984.27, 927.02, 985.01, and 965.17; AOAC, 1996), p-Anisidine value (Method Cd 18-90; AOCS, 2017), fat by acid hydrolysis (Method 954.02; AOAC, 1977), fatty acid profile (Methods Ce 2-66 and Ce 1b-89; AOCS, 2017), and free fatty acids (Method 940.28; AOAC, 2012 and Method Ca 5a-40; AOCS, 2017).

Soybean meal samples were ground and analyzed in duplicate for Ca and P (Method 985.01 A, B, and D; Method 942.05; AOAC, 2006; Table 2). Soybean meal samples were also analyzed in duplicate for proximate composition including dry matter (DM; Method 930.15; AOAC, 1999), crude protein (Method 990.03; AOAC, 2002), ether extract (Method 2003.05; AOAC, 2006), crude fiber (Method Ba 6a-05; AOCS, 2017), and ash (Method 942.05; AOAC, 2005), as well as neutral detergent fiber (NDF) using Ankom technology (Method 2001.11; AOAC, 2005). A sample of soybean meal was submitted for analysis of trypsin inhibitor activity in triplicate utilizing procedures outlined by Kim and Krishnan (2023).[9]

Statistical analysis

Data were analyzed using the lmer function from the lme4 package in R (version 2023.12.0 (2023-12-17), R Foundation for Statistical Computing, Vienna, Austria). For by-product analysis, soybean by-product type (soybean gums or soybean soapstocks) served as the fixed effect. For soybean meal analysis, soybean meal by-product inclusion (no by-products added, or by-products added) served as the fixed effect. Sample was included as a random effect to account for duplicate analysis. All results were considered significant with $P \leq 0.05$ and marginally significant with $P \leq 0.10$. Descriptive statistics were included to show the simple means of each analytical criteria within by-product or soybean meal type and timepoint of sample collection. Additionally, the range was included, which represented the minimum and maximum values for each analytical criteria within the soybean by-product or soybean meal type and timepoint of sample

[9] Kim, S., and H. B. Krishnan. 2023. A fast and cost-effective procedure for reliable measurement of trypsin inhibitor activity in soy and soy products. Methods Enzymol. 680:195-213. doi:10.1016/bs.mie.2022.08.016.

collection. The range was based on an individual analysis and does not represent the values of a sample analyzed in duplicate.

Results and Discussion

For the soybean by-product analysis (as-is), soybean gums had a greater ($P \leq 0.05$) percentage of acid hydrolyzed fat and p-Anisidine value compared to soybean soapstocks (Table 3). However, soybean soapstocks tended to have a greater ($P = 0.085$) percentage of moisture and volatile matter, as well as an increased ($P = 0.052$) concentration of insoluble impurities compared to soybean gums. As a percentage of the extracted fat, soybean soapstocks tended to have increased ($P = 0.085$) concentrations of the fatty acid C18:1 which resulted in a tendency for increased ($P = 0.085$) total monounsaturated fatty acids (MUFA) compared to soybean gums. Inversely, as a percentage of the extracted fat, soybean gums tended to have increased ($P = 0.056$) concentrations of the fatty acid C18:2, which translated into a tendency for increased ($P = 0.082$) total polyunsaturated fatty acids (PUFA) compared to soapstocks.

For the soybean meal analysis, soybean meal containing added soybean by-products had a 61% increase ($P < 0.05$) in ether extract compared to soybean meal samples not containing added soybean by-products on a DM basis (Table 4). There was no evidence of differences ($P > 0.10$) in any other analytical criteria due to by-product inclusion.

For acid hydrolyzed fat (as-is; Figure 1) and moisture and volatile matter (as-is; Figure 2) content, there was considerable variation regardless of soybean by-product type between processing plants. Similarly, when examining the effect of soybean processing plant on soybean meal composition, there was considerable variation in ether extract (as-is); however, a large portion of the variation was driven by soybean by-product inclusion (Figure 3). Trypsin inhibitor activity also varied considerably between plants with values ranging from 1.45 to 9.26 TIU/mg of seed powder (as-is; Figure 4).

In summary, these data suggest soybean gums had a greater acid hydrolyzed fat content and a decreased moisture and volatile matter percentage than soybean soapstocks. Most notably, there was considerable variation in by-product composition between processing plants indicating differences in processing procedures or incoming soybean quality. When soybean by-products were added back to soybean meal, there was an increase in ether extract, but no effects on crude protein. Ultimately, soybean meal containing greater than approximately 1.6% ether extract on a DM basis likely contains soybean by-products. These results provide information on the current composition and variation of soybean by-products across various processing plants; however, further information is still needed to evaluate their subsequent impact on livestock diets.

Table 1. Soybean by-product lipid quality analysis by by-product type and sampling timepoint (as-is)[1,2]

	Timepoint 1[3]				Timepoint 2			
	Gums		Soapstocks		Gums		Soapstocks	
Item	Mean	Range[4]	Mean	Range	Mean	Range	Mean	Range
Moisture and volatile matter, %	17.43	0.15-48.79	31.38	12.17-60.42	17.90	0.89-60.63	25.75	2.99-51.40
Insoluble impurities, %	0.26	0.05-0.86	2.85	0.14-6.82	1.60	0.09-6.84	14.42	0.00-46.78
Unsaponifiable matter, %	0.55	0.26-0.85	0.50	0.28-0.95	0.58	0.30-0.79	0.61	0.07-1.06
P, %	1.10	0.42-1.60	0.59	0.16-1.03	1.04	0.52-1.56	1.16	0.07-2.29
p-Anisidine value, %	22.9	1.3-58.9	2.1	0.0-4.1	3.3	0.0-19.4	2.4	0.0-4.6
Fat by acid hydrolysis, %	46.48	19.00-74.03	22.72	6.85-37.87	46.95	20.07-72.94	29.09	0.77-52.70
SFA, %[5]								
C16:0	14.76	10.53-16.27	14.22	11.97-16.25	14.51	11.31-15.79	13.92	9.52-17.23
C17:0	0.12	0.10-0.14	0.09	0.00-0.15	0.11	0.00-0.14	0.10	0.00-0.14
C18:0	4.26	3.81-4.84	4.40	3.35-5.16	4.22	3.55-5.17	4.15	3.57-4.82
C20:0	0.22	0.18-0.27	0.18	0.00-0.36	0.23	0.15-0.37	0.20	0.00-0.32
C22:0	0.41	0.37-0.52	0.48	0.37-0.74	0.45	0.35-0.92	0.37	0.00-0.50
C24:0	0.24	0.20-0.33	0.32	0.18-0.59	0.28	0.21-0.67	0.24	0.00-0.38
Total SFA	20.05	15.68-22.15	19.82	17.93-22.06	19.89	15.80-22.20	20.20	15.69-25.27
MUFA, %[5]								
C16:1	0.08	0.00-0.18	0.08	0.00-0.18	0.20	0.00-0.29	0.20	0.00-0.29
C18:1[6]	13.91	10.24-18.26	15.75	10.93-20.22	15.76	13.23-20.17	21.90	13.07-52.90
C20:1[6]	0.09	0.00-0.18	0.10	0.00-0.22	0.21	0.14-0.52	0.18	0.00-0.29
Total MUFA	14.11	10.34-18.49	15.93	10.93-20.48	16.22	13.69-20.66	22.31	13.61-52.90
PUFA, %[5]								
C18:2[6]	57.19	54.89-62.43	55.86	52.87-63.27	56.89	53.16-62.94	50.52	25.00-59.20
C18:3[6]	7.68	6.86-8.37	7.73	7.33-8.00	7.00	5.39-7.83	6.97	3.57-9.28
Total PUFA	64.87	61.75-69.94	63.58	60.74-71.14	63.90	60.11-69.29	57.50	28.57-67.22
Free fatty acids, %[5]	9.69	3.14-15.91	7.10	0.16-21.40	10.14	6.20-33.00	7.58	2.40-20.80

[1]A total of 36 soybean by-product samples from 14 soybean processing plants across eight different companies were used in an industry survey with 12 soybean gums and six soybean soapstocks submitted at each sampling timepoint.
[2]All samples were analyzed in duplicate.
[3]Samples were collected at two timepoints within the survey: May to July 2023 and October to November 2023.
[4]The range is the minimum and maximum value for each analytical criteria within soybean by-product type and timepoint of sample collection. Values represent an individual analysis and are not representative of the criteria in duplicate.
[5]Presented as a percentage of extracted lipid.
[6]Concentration includes isomers.
MUFA = monounsaturated fatty acids. PUFA = polyunsaturated fatty acids. SFA = saturated fatty acids.

Table 2. Soybean meal analysis by by-product inclusion and sampling timepoint, DM basis[1,2]

	Timepoint 1[3]				Timepoint 2			
	No by-products added		By-products added		No by-products added		By-products added	
Item	Mean[4]	Range[5]	Mean	Range	Mean	Range	Mean	Range
DM, %	87.24	85.80-88.19	87.73	86.93-88.68	87.40	86.69-88.48	87.22	86.28-88.14
Crude protein, %	53.22 (46.43)	50.98-56.33	53.33 (46.79)	51.47-55.00	53.28 (46.57)	52.47-55.17	52.89 (46.14)	51.07-54.01
Ether extract, %	1.15 (1.00)	0.91-1.60	1.95 (1.72)	1.17-3.35	1.03 (0.90)	0.84-1.31	1.56 (1.36)	1.02-2.20
Crude fiber, %	5.99 (5.23)	4.01-7.39	5.89 (5.16)	4.41-8.35	4.58 (4.00)	3.53-5.26	4.87 (4.25)	3.95-6.15
Ash, %	6.62 (5.77)	6.05-7.98	6.65 (5.83)	6.02-8.13	6.63 (5.79)	6.23-7.09	6.68 (5.83)	6.24-7.27
Neutral detergent fiber, %	9.04 (7.88)	6.20-12.90	8.22 (7.21)	5.36-10.57	7.40 (6.47)	6.18-8.92	8.08 (7.04)	6.36-9.91
P, %	0.73 (0.64)	0.68-0.81	0.72 (0.63)	0.69-0.77	0.78 (0.68)	0.73-0.83	0.76 (0.67)	0.69-0.81
Ca, %	0.40 (0.35)	0.27-0.83	0.65 (0.57)	0.29-2.27	0.39 (0.34)	0.25-0.64	0.50 (0.44)	0.29-0.96
TIA, TIU/mg seed powder	6.31 (5.50)	4.33-9.81	6.52 (5.72)	3.79-10.57	6.30 (5.50)	1.67-9.85	6.49 (5.65)	3.94-7.98

[1]A total of 26 soybean meal samples were collected. At both timepoints, seven soybean meal samples contained added by-products, and six samples did not contain added by-products.
[2]All analyses besides trypsin inhibitor activity were run in duplicate. Trypsin inhibitor activity was analyzed in triplicate.
[3]Samples were collected at two timepoints within the survey: May to July 2023 and October to November 2023
[4]Analytical results are reported on a DM basis except for DM percentage. Values in parentheses represent the means on an as-is basis.
[5]The range is the minimum and maximum value for each analytical criteria within soybean meal by-product inclusion type and timepoint of sample collection. Values represent an individual analysis and is not representative of the criteria in duplicate.
DM = dry matter. TIA = trypsin inhibitor activity.

Table 3. Effects of soybean by-product type on lipid quality analysis (as-is)[1,2]

	Soybean by-product			
Item	Gums	Soapstocks	SEM	*P* =
Moisture and volatile matter, %	17.67	28.57	5.00	0.085
Insoluble impurities, %	0.93	8.63	2.975	0.052
Unsaponifiable matter, %	0.56	0.55	0.055	0.902
P, %	1.07	0.89	0.120	0.242
p-Anisidine value, %	13.09	2.23	3.692	0.021
Fat by acid hydrolysis, %	46.72	25.90	4.457	< 0.001
SFA, %[3]				
C16:0	14.64	14.07	0.525	0.386
C17:0	0.12	0.09	0.012	0.165
C18:0	4.24	4.28	0.125	0.810
C20:0	0.23	0.19	0.025	0.191
C22:0	0.43	0.43	0.037	0.973
C24:0	0.26	0.28	0.030	0.714
Total SFA	19.97	20.01	0.566	0.953
MUFA, %[3]				
C16:1	0.14	0.14	0.020	0.935
C18:1[4]	14.83	18.83	1.834	0.085
C20:1[4]	0.15	0.14	0.022	0.658
Total MUFA	15.16	19.12	1.817	0.085
PUFA, %[3]				
C18:2[4]	57.04	53.19	1.588	0.056
C18:3[4]	7.34	7.35	0.228	0.964
Total PUFA	64.39	60.54	1.750	0.082
Free fatty acids, %[3]	9.91	7.34	1.886	0.267

[1]Samples were collected at two timepoints within the survey: May to July 2023 and October to November 2023. All samples were analyzed in duplicate.
[2]A total of 24 soybean gums and 12 soybean soapstocks were analyzed at two different timepoints from 14 soybean processing plants across eight different companies.
[3]Presented as a percentage of extracted lipid.
[4]Concentration includes isomers.
MUFA = monounsaturated fatty acids. PUFA = polyunsaturated fatty acids. SFA = saturated fatty acids.

Table 4. Effects of soybean meal by-product inclusion on soybean meal composition, DM basis[1,2]

	Soybean meal by-product inclusion			
Item	No by-products added[3]	By-products added	SEM	*P* =
DM, %	100 (87.32)	100 (87.48)	0.158	0.472
Crude protein, %	53.25 (46.50)	53.11 (46.46)	0.331	0.764
Ether extract, %	1.09 (0.95)	1.76 (1.54)	0.132	0.001
Crude fiber, %	5.28 (4.61)	5.38 (4.71)	0.226	0.760
Ash, %	6.63 (5.79)	6.65 (5.82)	0.122	0.803
Neutral detergent fiber, %	8.22 (7.18)	8.15 (7.13)	0.268	0.846
P, %	0.76 (0.66)	0.74 (0.65)	0.009	0.198
Ca, %	0.40 (0.35)	0.58 (0.51)	0.108	0.232
TIA, TIU/mg seed powder	6.31 (5.51)	6.50 (5.69)	0.565	0.815

[1]Samples were collected at two timepoints within the survey: May to July 2023 and October to November 2023. All analyses besides trypsin inhibitor activity were run in duplicate. Trypsin inhibitor activity was analyzed in triplicate.
[2]A total of 26 soybean meal samples were collected. At both timepoints, seven soybean meal samples contained added by-products, and six samples did not contain added by-products.
[3]Analytical results and statistics are reported on a DM basis besides DM percentage, which is on an as-is basis. Values in parentheses represent the model adjusted means on an as-is basis calculated by utilizing the treatment analyzed dry matter percentage.
DM = dry matter. TIA = trypsin inhibitor activity.

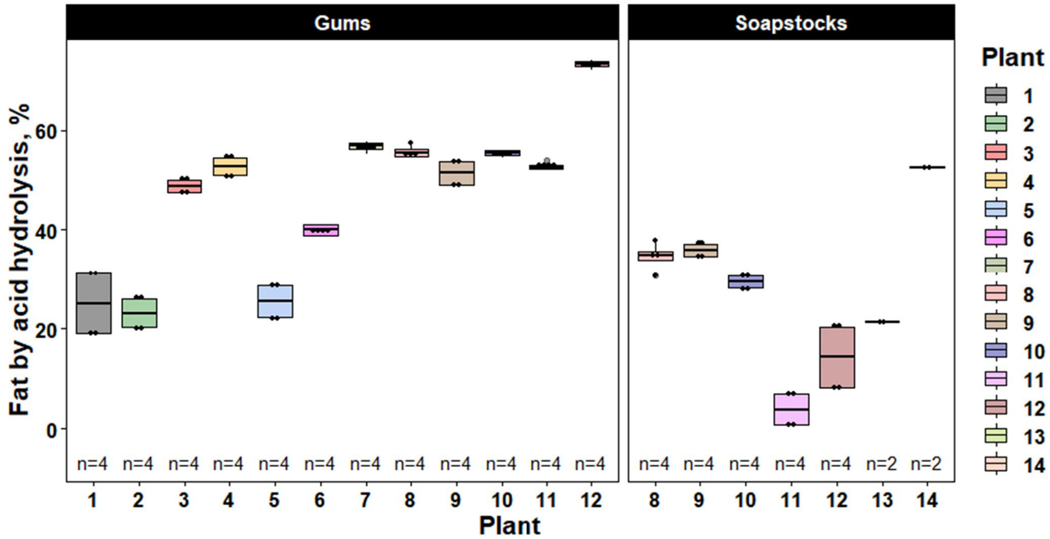

Figure 1. Fat by acid hydrolysis of soybean by-product samples by soybean processing plant and soybean by-product type (as-is)

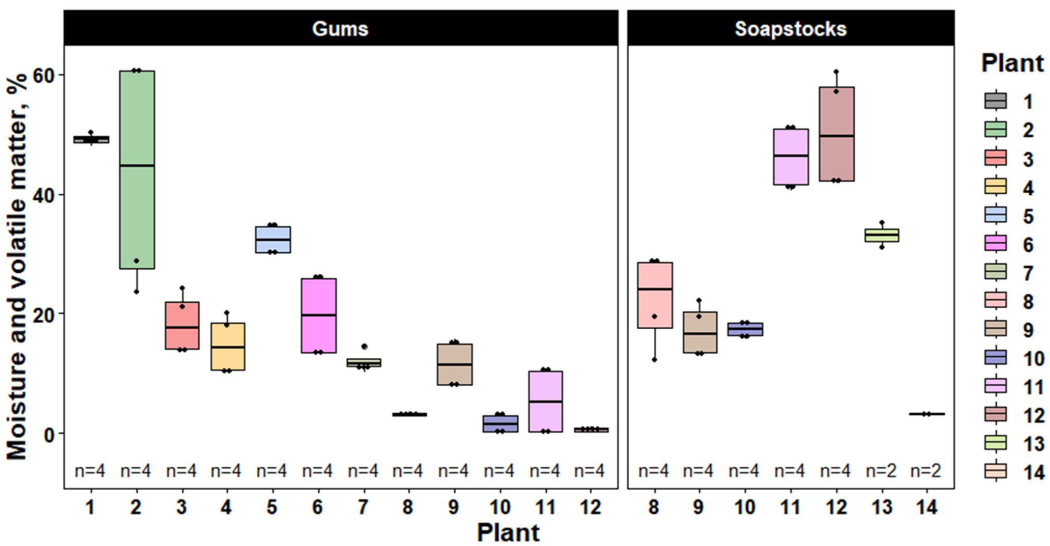

Figure 2. Moisture and volatile matter of soybean by-product samples by soybean processing plant and soybean by-product type (as-is)

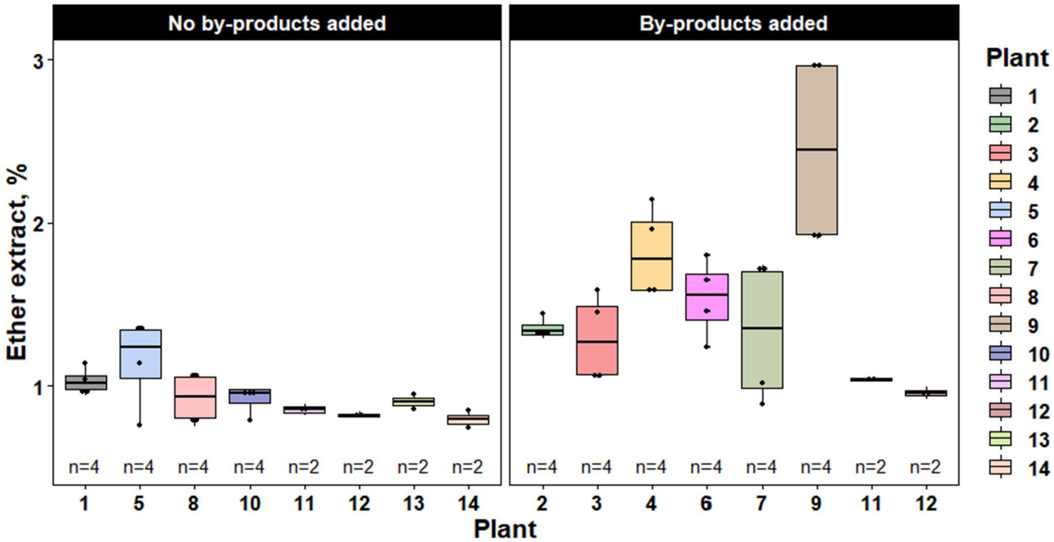

Figure 3. Ether extract of soybean meal samples by soybean processing plant and soybean by-product inclusion (as-is)

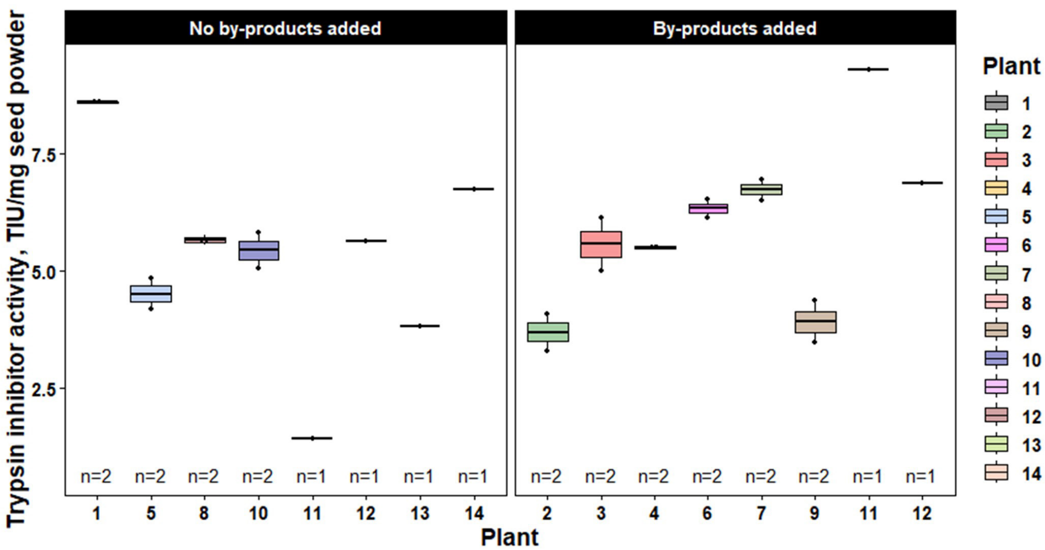

Figure 4. Trypsin inhibitor activity of soybean meal samples by soybean processing plant and soybean by-product inclusion (as-is)