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Soon Soon ASAIM soybean meal NIR project final report

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1.0 BACKGROUND

The quality of soybeans and soybean meals is variable especially in Asian countries where a large proportion of these commodities are imported. Similarly, the crushing plants in Asia use soybeans from many different origins.

Measuring the nutrient content of raw materials by NIR is currently in use by the feed industry with variable success. Calibrations developed by EvonikDegussa and Adisseo are the most reliable to date. However, these calibrations are proprietary and not freely available. Furthermore, not all quality parameters are measured such as Trypsin inhibitor activity (TIA) and Protein Dispersibility Index (PDI). Therefore a large scale global collection of soybean meal samples from various origins will be useful to establish and quantify the quality differences. At the same time, the quality data generated will be used to obtain universal NIR calibrations for each quality parameters thus allowing crushers and feed-millers to quantify these differences and use them to make better purchasing decisions and formulate more accurate feeds.

NIR has been used in soybeans and soybean meals to calibrate proximate analysis parameters such as protein, fiber, oil content and moisture. For soybean meal, some attempts have been made to calibrate amino acid content, digestible lysine and apparent metabolizable energy (AME). However, the accuracy of prediction of these parameters has not been good enough to gain wide commercial acceptance. Furthermore, calibrations for essential quality parameters such as Trypsin inhibitor activity (TIA), KOH protein solubility (KOHPS) and Protein dispersibility index (PDI) are not commercially available.

2.0 OBJECTIVE

The purpose of this study was to collect 200 samples of soybean meals (100 for phase 1 and 100 for phase 2) from various origins to build global NIR calibrations for the proposed quality parameters as listed below.

- Moisture
- Crude Protein
- Crude Oil
- Ash
- Crude Fiber
- Neutral detergent fiber (NDF)
- Protein Dispersibility Index (PDI)
- KOH Protein Solubility (KOHPS)
- Delta pH
- Trypsin Inhibitor Activity (TIA)
- Colour (L/a/b)

3.0 MATERIALS AND METHODS

The above parameters were tested using internationally recognized reference methods, by SS Laboratory Services Sdn Bhd, an ISO17025 accredited laboratory affiliated with Soon Soon Group.

Amount of sample used per soybean meal was 2 kg. The samples were collected based on a collaboration between Soon Soon Group (SSG) and American Soybean Association (ASA).

Each sample was homogenized and separated via Boerner Divider into 4 separated packs. One sample was kept in the freezer as a reference. Another three packets of samples were ground to different sizes prior to lab test. All scanning was completed within 24 hours of registration and the sample was immediately submitted to the respective person in charge for laboratory testing. Moisture, PDI and KOHPS were completed within 24-48 hours after scanning. The rest was completed within 7 days of registration.

A NIR Systems with scanning monochromator and equipped with transport module was used to measure reflectance spectra from 400 to 2498nm, every 2nm. Absorbance value was recorded as log 1/R, where R is the sample reflectance. The analysis of unground soybean meal samples was carried out using rectangular ¼ cup. Sample was scanned at ambient temperature 25^{o}C for optimum performance. Analyzing at a temperature higher or lower than the environment temperature increases the risk for moisture condensation or moisture evaporation from the sample and temperature drift during the analysis.

Calibrations were developed using NIR software. The modified partial least squares (MPLS) regression method was used to obtain NIR equations for all the parameters. The mean of the data base was calculated and the distance from this mean to each sample was calculated. The boundary was set to 3 standard deviations for the data set. Samples which are out of the boundary were deleted.

4.0 RESULTS & DISCUSSIONS

4.1 NIR Calibrations Evaluation

Soybean meal samples have been collected and calibrated to build a global equation. 31.8% of the collected soybean meals were from soybeans originating from US, 21.4% from Argentine, 15.9% from India, 11.9% from Brazil, 11.0% from Canada and 8.0% from others countries which consisted of China, and Thailand. For the validation samples, 35.0% of the soybean meals were from soybean originating from US, 30.0% from Argentine, 10.0% from India, 15.0% from Brazil, 7.5% from Canada and lastly 2.5% from China. The origin distributions of soybean meals for calibration and validation are shown in Figure 1.

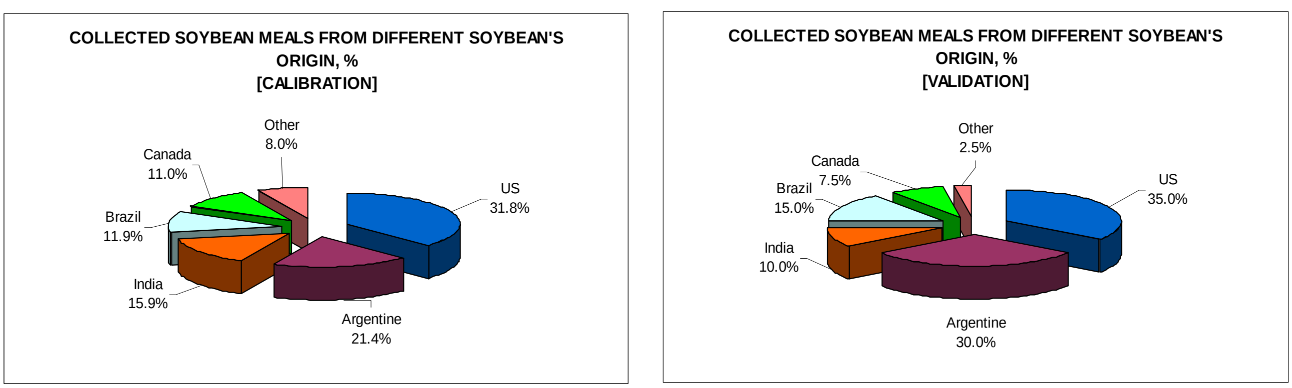

Figure 1: The distribution of soybean meal produced from soybeans of different origins which were used for calibration and validation.

Calibration statistics for predicting the chemical composition (%) of soybean meal samples were tabulated in Table 1.

Results from the regression of the samples show that the NIR Global Calibration Project appear to be successful. Most of the parameters show good correlation coefficients with RSQ of more than 0.9, except KOHPS and delta pH. A correlation of 1.0 indicates a perfect agreement between the predicted results with the reference set of data. The SEC values of those parameters are similar or less than 1.5 times the reproducibility of the reference laboratory test methods. This indicates that the accuracy and the precision of the calibrations are reliable. Regression results from NIRS for ash were normally found to be poor by other researchers. It was assumed to be because NIRS has difficulty measuring minerals as minerals do not absorb light in the near-infrared region. However, in our case, ash has shown a good correlation 0.9728 and standard error of calibration 0.30.

These global equations were validated with 40 soybean meal samples from soybeans of various origins. Validation statistics for predicting chemical composition (%) of these soybean meals are shown in table 2. The equations for moisture, oil, crude fiber, ash and delta pH also show good capacity for quality control where all of the parameters have SEP less than 0.5. Calibrations for essential quality parameters which need tedious wet analysis such as PDI, KOHPS and TIA show good prediction with SEP 5.82, 4.13 and 0.55 respectively.

Quality distribution for the samples collected for this NIR calibration project are illustrated in Chart 1.1-1.13. In order to improve the accuracy of the NIR calibrations, an even distribution of quality range is required. Therefore certain quality ranges which is not well populated still need to be filled up.

Table 1: Calibration statistics for predicting chemical composition (%) of soybean meals (N=160)

	Min	Max	SEC	RSQ	SECV
Moisture	9.7	14.2	0.1151	0.9808	0.1421
Protein	39.5	49.3	0.1877	0.9456	0.2634
Oil	0.56	3.47	0.1100	0.9631	0.1444
PDI	12.6	56.6	2.2591	0.9348	2.8199
KOHPS	67.3	92.0	1.2602	0.8732	1.6553
Crude Fiber	2.0	8.6	0.1602	0.9820	0.2287
Ash	5.49	8.89	0.3015	0.9728	0.4300
TIA	0.8	4.5	0.1374	0.9418	0.1677
NDF	5.0	16.9	0.1904	0.9263	0.2477
Delta pH	0.01	0.46	0.0090	0.7772	0.0116
Colour ‘L’	52.66	77.05	0.7609	0.9529	0.9218
Colour ‘a’	1.20	5.91	0.1548	0.9783	0.2125
Colour ‘b’	13.65	20.14	0.2349	0.9751	0.3116

Min: minimum value; Max: maximum value; SEC: standard error of calibration; RSQ: R square; SECV: standard error of cross-validation.

Table 2: Validation statistic for predicting chemical composition (%) of soybean meals (N=40)

	Min	Max	Mean	SEP
Moisture	10.1	13.4	11.6	0.297
Protein	42.5	49.9	46.7	0.628
Oil	0.38	3.16	1.87	0.273
PDI	10.2	52.9	27.2	5.818
KOHPS	69.8	90.3	81.4	4.129
Crude Fiber	2.2	6.2	3.4	0.521
Ash	5.54	7.8	6.56	0.318
TIA	0.8	4.0	2.0	0.553
NDF	5.0	12.1	7.8	0.909
Delta pH	0.01	0.1	0.02	0.019
Colour 'L'	53.46	68.65	60.97	1.748
Colour 'a'	1.98	6.23	3.63	0.520
Colour 'b'	12.29	18.30	16.26	0.857

Min: minimum value; Max: maximum value; SEP: standard error of prediction

4.2 Soybean Meal Quality Evaluation

The average moisture content for the 200 soybean meal samples was 11.6%. Almost 8.0% of the soybean meals have moisture content lower than 12.0%. However, there were two soybean meals from Argentine and Indian soybeans with extremely high moisture content, 14.2% and 14.0% respectively. Soybean meals crushed by Soon Soon Oilmill have comparatively low moisture as compared to other crushers although they are from the same origin. The average moisture content in the ascending order based on origin from US (lowest), Argentine, Brazil, India, Canada and lastly China (highest). (Chart 1.1)

The protein content for all the soybean meal samples were compared on a constant moisture (12.0%) and constant oil (1.0%) basis. The average value of the protein content was 46.6%. Standard deviation between the protein content of all soybean meals was 1.3. This high standard deviation value was due to some of the collected samples being only partially dehulled while some were non-dehulled. The protein content of soybean meals produced from Brazilian and Canadian soybeans were comparatively higher when compared to other origins. 66.7% and 54.5% of the soybean meals from Brazilian and Canadian soybeans had protein contents higher than 47.0%. The average protein content of soybean meals based on soybean origin increased from China (lowest), India, Argentine, US, Canada and finally Brazil (highest). (Chart 1.2)

Most of the oil content of soybean meal from different origins was lower than 2.5%. Only 11.0% of them had oil content higher than 2.5%. Soybean meals from soybean of Indian and Chinese had significantly lower oil content which is 1.10 and 1.05 respectively. This indicates that lecithin was not added into the meals. Soybean meals produced from US soybeans by Soon Soon

Oilmill had comparatively high oil content. The average oil content based on soybean origin increased from China (lowest), India, Canada, Brazil, Argentine to lastly US soybean meal (highest). (Chart 1.3)

Soybean meals produced from Canadian soybeans had higher PDI content as compared to others origin. All of the Canadian soybean meals collected were crushed by Soon Soon Oilmills. 100% of the Canadian soybean meals had PDI higher than 30.0%. Soybean meals produced from Brazilian soybeans had comparatively lower PDI content, 22.0%. The average PDI content of soybean meals from Argentine soybeans was 22.1%. However, there was one extraordinary Argentine sample crushed by Soon Soon Oilmill with PDI content higher than 35.0%. The average PDI of all the different soybean meals samples was 30.1%. The average PDI content of the soybean meals based on soybean origin increased from Brazil (lowest), Argentine, US, India, Canada, to China (highest). (Chart 1.4) However there were only four samples from China, thus the results obtained may not be representative.

The KOHPS content of soybean meal ranged from 67.3 to 92.0%. Soybean meals from US soybeans showed higher KOHPS value as compared to others origin. The average KOHPS content of the soybean meals from various origins was 82.4%. This shows that most of the samples were of reasonably good quality except samples from Brazil, where the KOHPS content was only 78.9%. 50.0% of the soybean meals from Brazilian soybeans had KOHPS less than 80.0%. The average KOHPS content increase based on soybean origin from Brazil (lowest), Argentine, China, Canada, India to the US (highest). (Chart 1.5)

Generally the crude fiber content of the soybean meal from different origins was lower than 3.5%. This was due to most of the samples being of dehulled soybean meal. However, there were some non-dehulled and partially dehulled samples collected from India, Thailand and some samples from Argentine and Brazil with crude fiber content higher than 5.0%. Meals from Canadian soybeans had comparatively low crude fiber content as compared to other origins, only 2.75% on average. The average crude fiber content increased based on soybean origin from Canada (lowest), Argentine, US, Brazil, China to lastly India (highest) where most of the samples were non dehulled soybean meals. (Chart 1.6)

The average and standard deviation values for NDF were 8.5% and 2.3%. Soybean meals crushed in Thailand, India and China had higher NDF value as compared to other crushers. 90.5% of the soybean meals from India had NDF value more than 10.0%, as most of them were non dehulled samples. The average NDF reading increased based on soybean origin from US (lowest), Argentine, Canada, Brazil, China to lastly India (highest). (Chart 1.7)

Typically, most of the soybean meal samples had ash content higher than 6.0%. The distribution did not show any significant differences between origin vs origin and crusher vs crusher. However, soybean meals from India showed ash value comparatively high as compared to others. The average value of the ash content for Indian soybean meal was 7.62%, which was

13.0% higher than the average value of soybean meals from all different countries. The average ash content increased based on soybean origin from China (lowest), Canada, Brazil, US, Argentine, to lastly India (highest). (Chart 1.8)

The TIA readings were ranged from 0.8-4.5mg/g. Soybean meals from Argentine soybeans showed the lowest TIA reading whereas meals from US soybeans showed the highest TIA reading. 95.3% of soybean meals from Argentine soybeans had TIA value below 2.5mg/g. Soybean meals collected by Indonesian feed millers had comparatively lower TIA contents. Only one out of nine samples had TIA content higher than 2mg/g. The average TIA reading increased based on soybean origin from Argentine (lowest), Canada, India, China, Brazil, to lastly US (highest). (Chart 1.9)

Generally, the delta pH of soybean meals fell between 0.01-0.04. Only 16.4% of the soybean meals had delta pH higher than 0.04. However there were some soybean meals from Argentine, Brazil and US that showed very high delta pH value above 0.08. The average delta pH values increased based on soybean origin was Canada (lowest), Argentine, China, US, Brazil to lastly India (highest). (Chart 1.10)

The parameter of colour was calibrated using the L/a/b system. The colour of L was calibrated ranging from 52.66 to 77.05, ‘a’ from 1.2 to 6.23 and ‘b’ from 11.74 to 20.14. Soybean meals from Brazilian soybeans with highest ‘a’ value had greater red colour as compared to others. Whereas soybean meals from US soybeans had highest ‘b’ value indicating they are more yellowish as compared to others origins. (Chart 1.11-1.13)

4. 3 Correlation of Quality Parameters

The correlations between various quality parameters were determined for PDI vs KOHPS, PDI vs TIA, PDI vs NDF, PDI vs Protein, KOHPS vs TIA, KOHPS vs NDF, KOHPS vs Protein, Crude fiber vs NDF, Crude Fiber vs Protein, Delta pH vs PDI, Delta pH vs KOHPS, Delta pH vs TIA, PDI vs L, PDI vs a, PDI vs b, KOHPS vs L, KOHPS vs a, and lastly KOHPS vs b. Only the following parameters pairs shown in the table below showed good or slight correlation. (Figure 2)

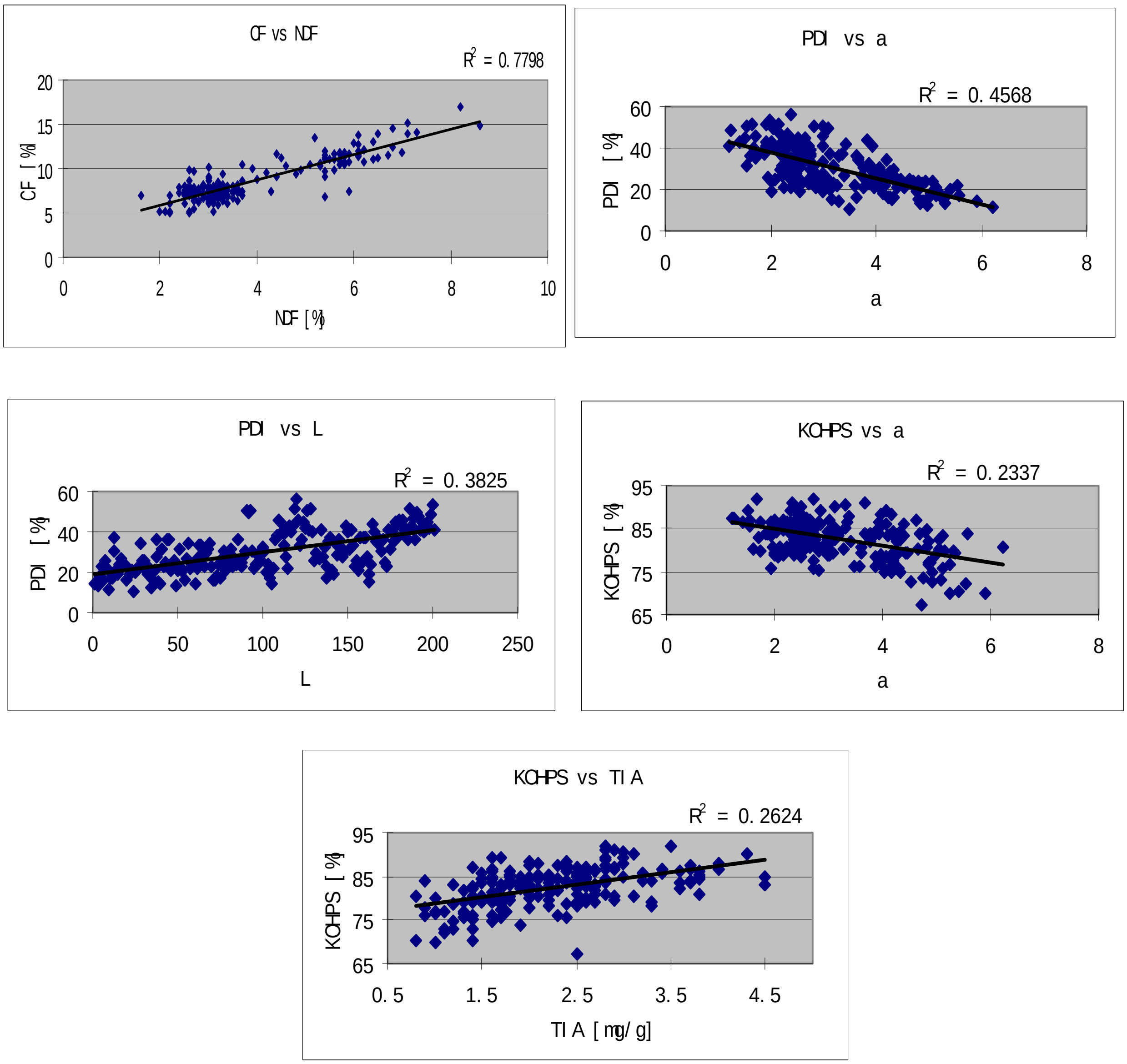

Figure 2: Parameter pairs with good or slight correlation.

Table 3: Soybean meals quality distribution based on origin.

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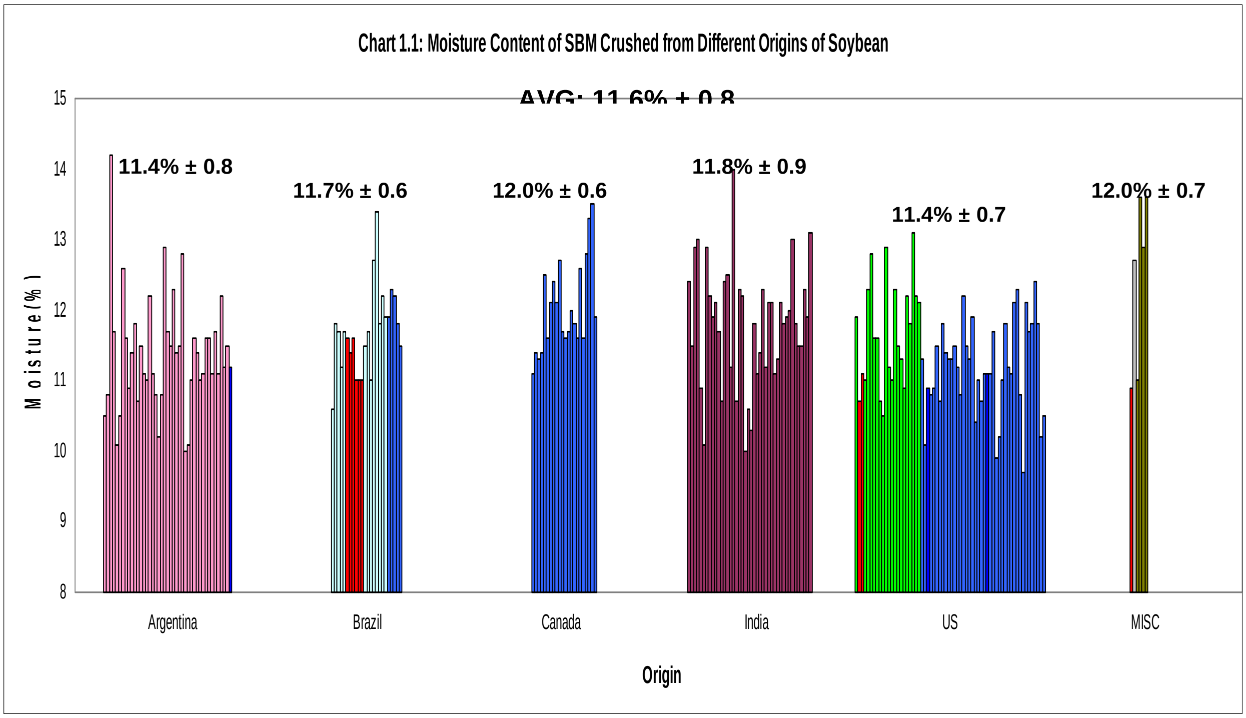
Soybean Meal Quality in Soon Soon ASAIM Soybean Meal NIR Project Based on Origin and Crusher (Charts 1.1-1.13)



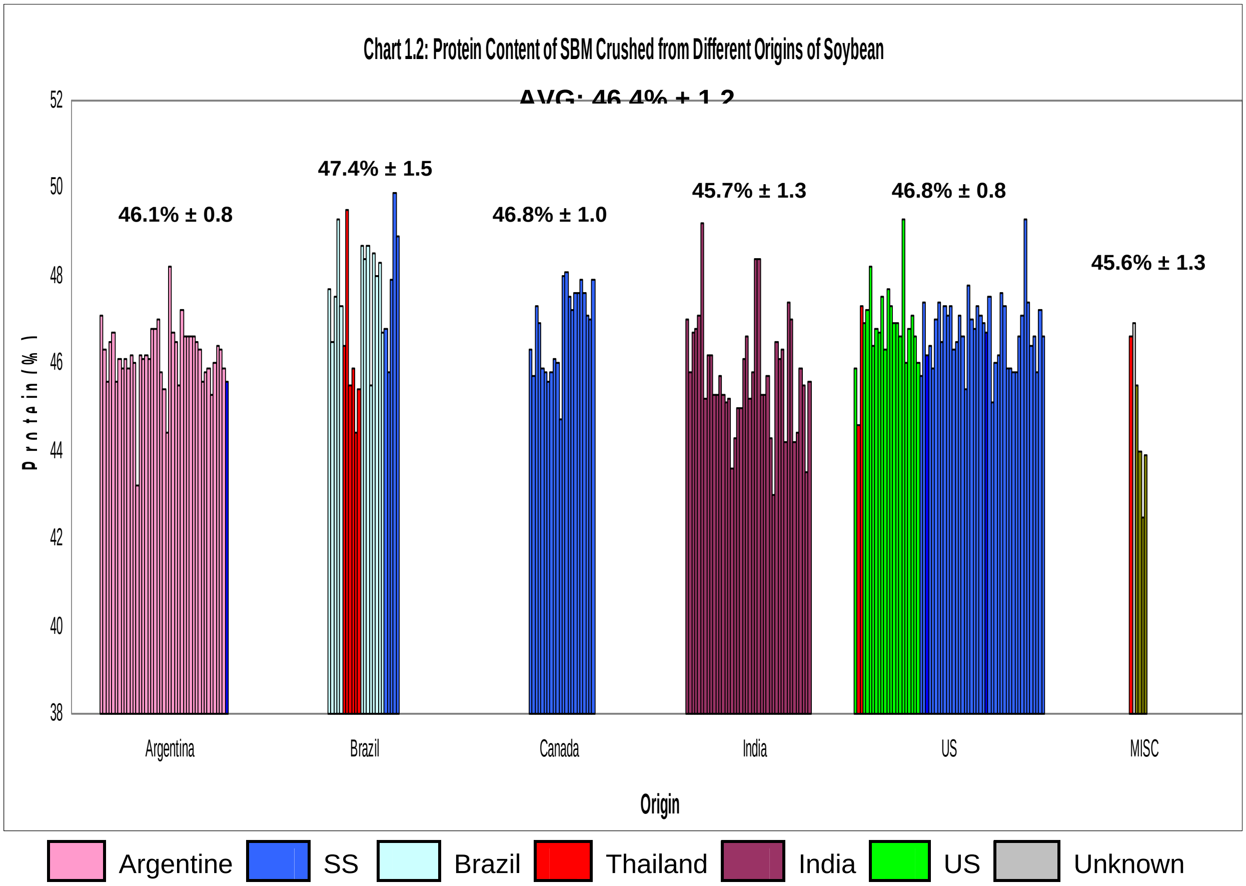


Chart 1.2: Protein Content of SBM Crushed from Different Origins of Soybean
AVG: 46.4% ± 1.2
Protein (%)
52
50
48
46
44
42
40
38
46.1% ± 0.8
47.4% ± 1.5
46.8% ± 1.0
45.7% ± 1.3
46.8% ± 0.8
45.6% ± 1.3
Argentina
Brazil
Canada
India
US
MISC
Origin
Argentine
SS
Brazil
Thailand
India
US
Unknown

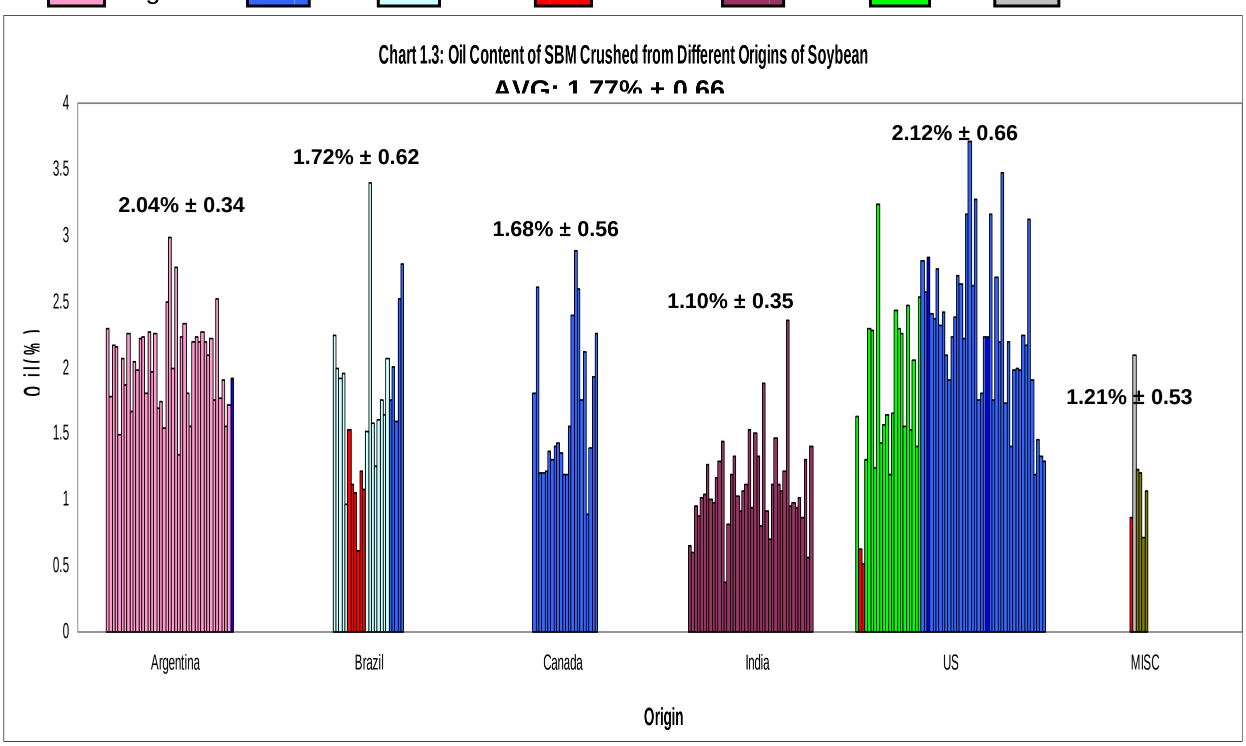


Chart 1.3: Oil Content of SBM Crushed from Different Origins of Soybean
AVG: 1.77% ± 0.66
Oil (%)
4
3.5
3
2.5
2
1.5
1
0.5
0
2.04% ± 0.34
1.72% ± 0.62
1.68% ± 0.56
1.10% ± 0.35
2.12% ± 0.66
1.21% ± 0.53
Argentina
Brazil
Canada
India
US
MISC
Origin

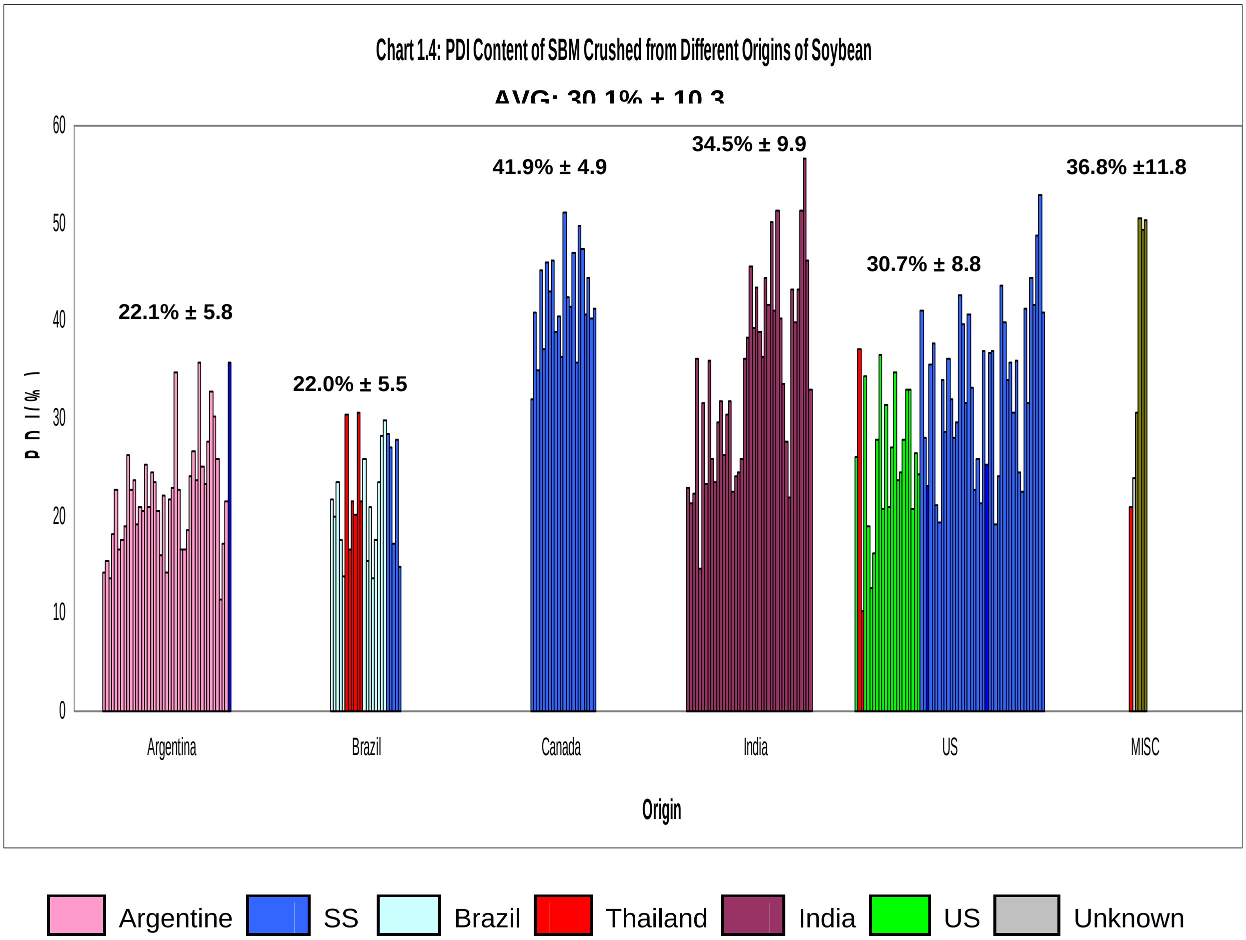


Chart 1.4: PDI Content of SBM Crushed from Different Origins of Soybean
AVG: 30.1% ± 10.3
P D I (%)
60
50
40
30
20
10
0
22.1% ± 5.8
22.0% ± 5.5
41.9% ± 4.9
34.5% ± 9.9
30.7% ± 8.8
36.8% ±11.8
Argentina
Brazil
Canada
India
US
MISC
Origin
Argentine
SS
Brazil
Thailand
India
US
Unknown

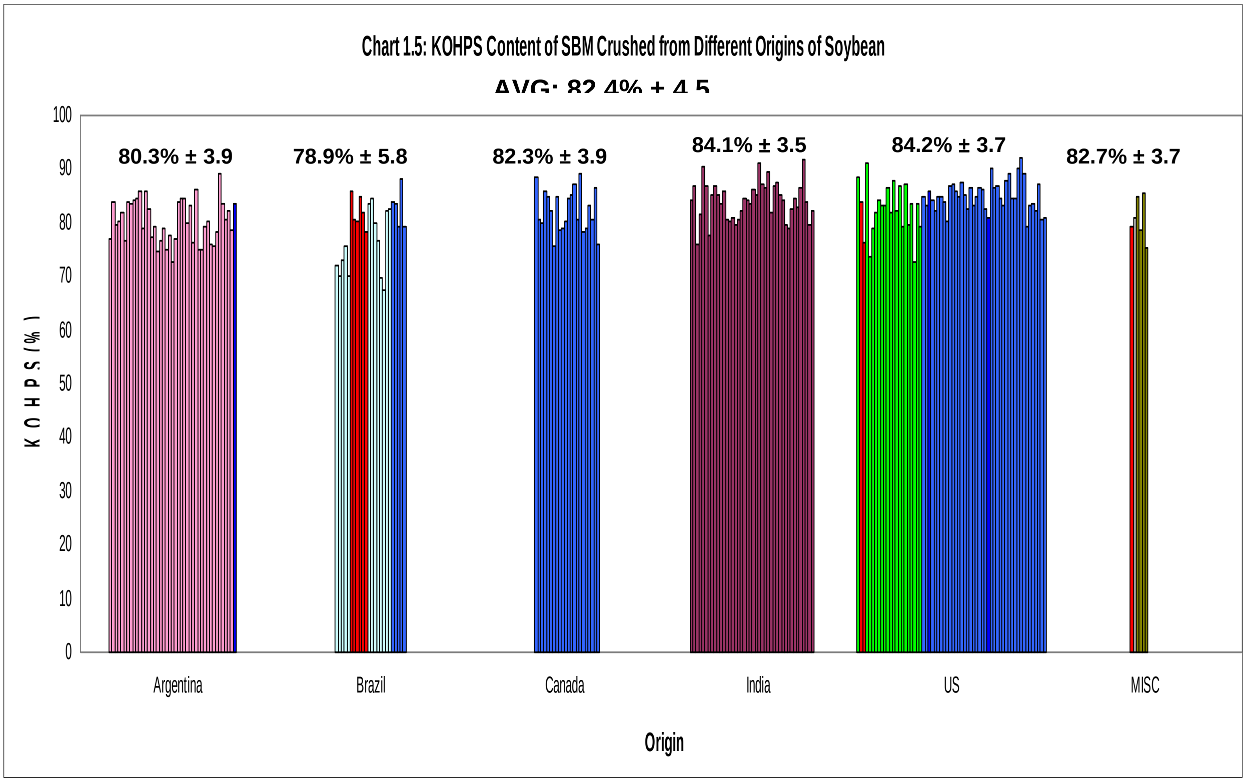


Chart 1.5: KOHPS Content of SBM Crushed from Different Origins of Soybean
AVG: 82.4% ± 4.5
K O H P S (%)
80.3% ± 3.9
78.9% ± 5.8
82.3% ± 3.9
84.1% ± 3.5
84.2% ± 3.7
82.7% ± 3.7
Argentina
Brazil
Canada
India
US
MISC
Origin

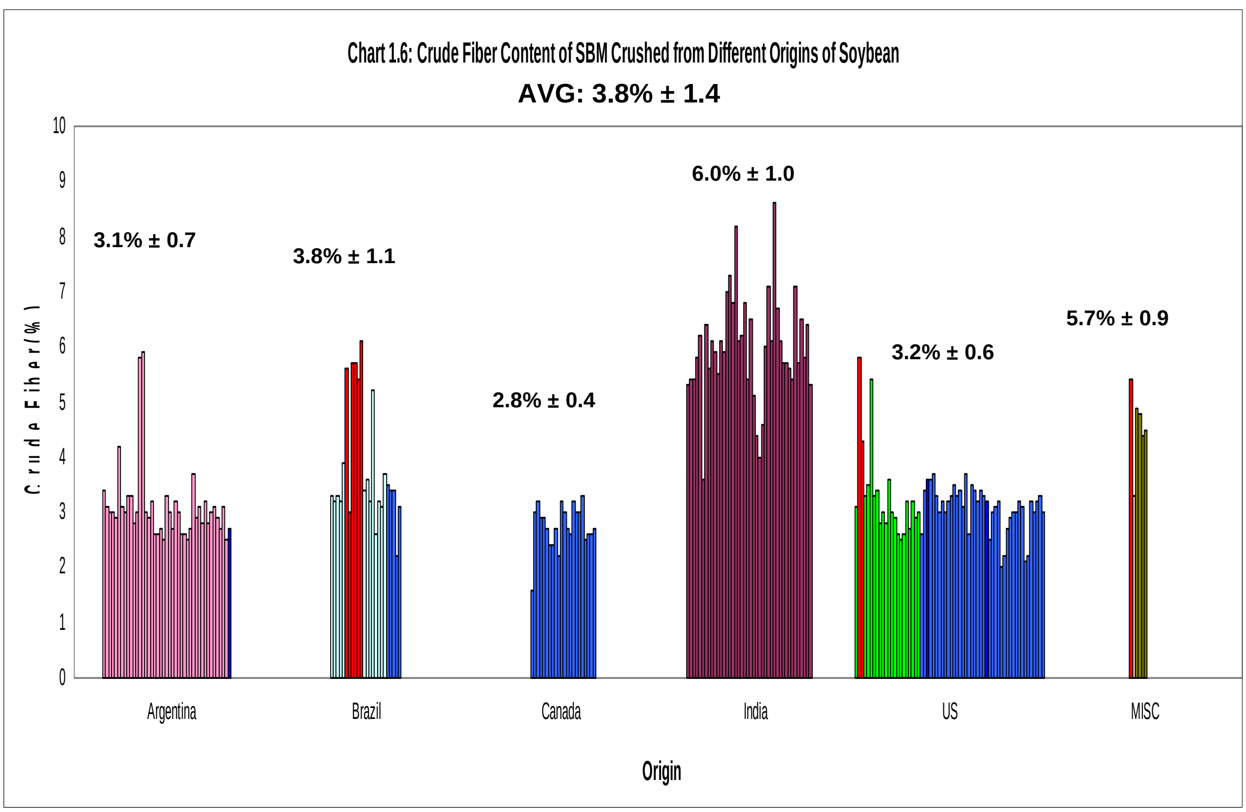
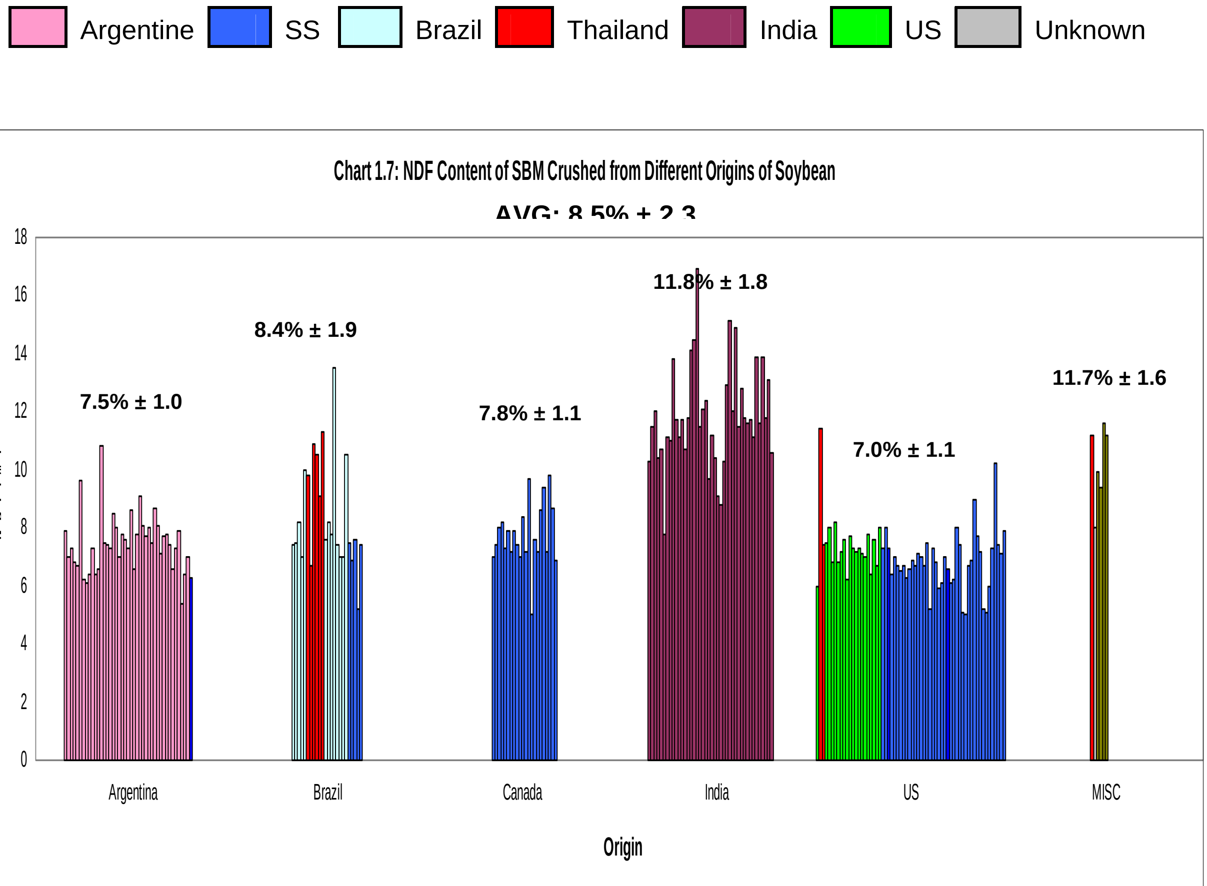


Chart 1.6: Crude Fiber Content of SBM Crushed from Different Origins of Soybean
AVG: 3.8% ± 1.4
3.1% ± 0.7
3.8% ± 1.1
2.8% ± 0.4
6.0% ± 1.0
3.2% ± 0.6
5.7% ± 0.9
Argentina
Brazil
Canada
India
US
MISC
Origin



AVG: 6.64% ± 0.69

7.62% ± 0.68

6.57% ± 0.33

6.24% ± 0.25

6.56% ± 0.36

7.51% ± 0.87

5.83% ± 0.18

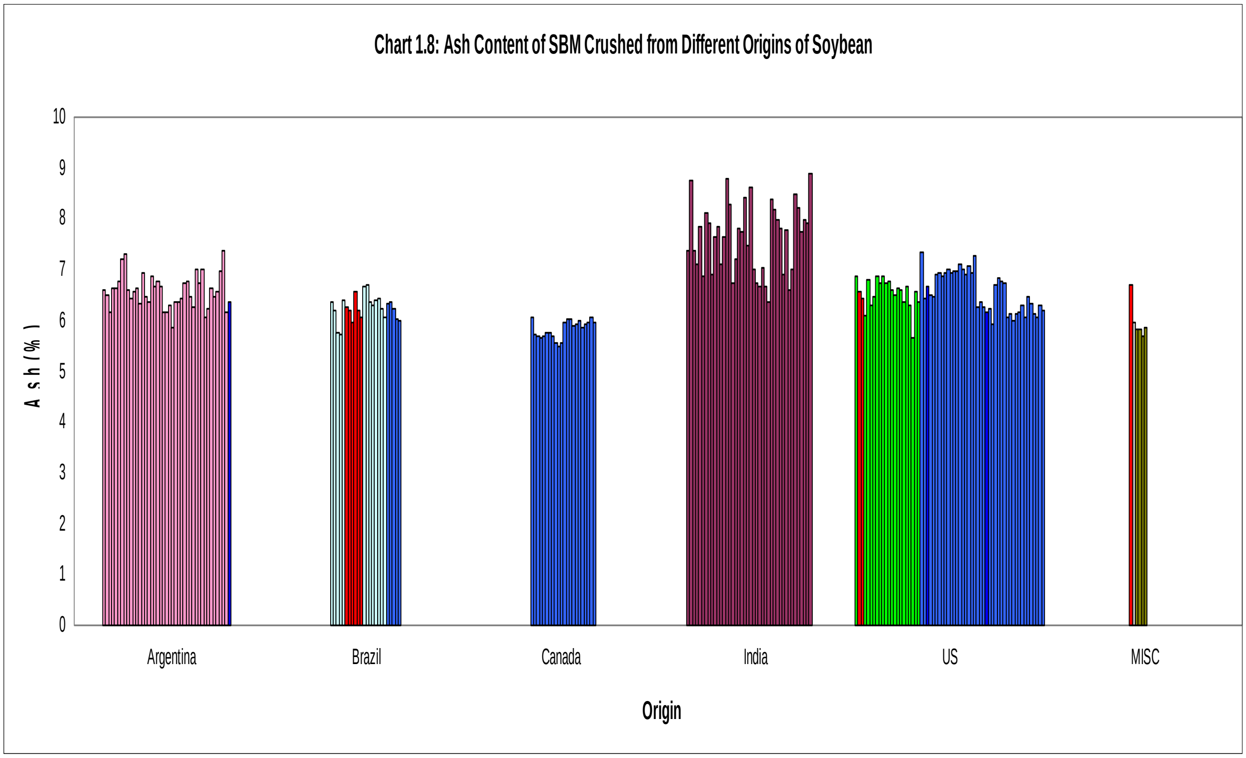
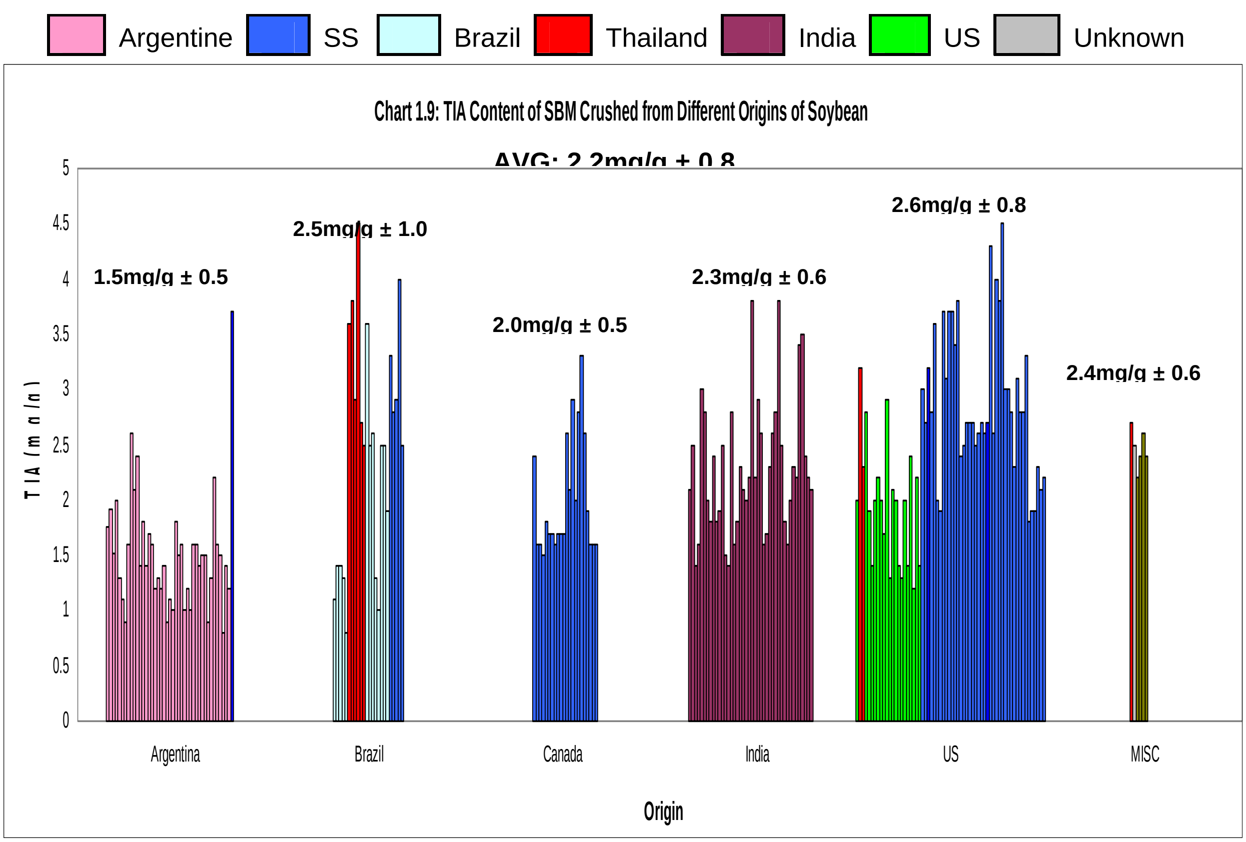


Chart 1.8: Ash Content of SBM Crushed from Different Origins of Soybean
A s h (%)
0
1
2
3
4
5
6
7
8
9
10
Argentina
Brazil
Canada
India
US
MISC
Origin


Argentine
SS
Brazil
Thailand
India
US
Unknown
Chart 1.9: TIA Content of SBM Crushed from Different Origins of Soybean
AVG: 2.2mg/g ± 0.8
T I A (m g / g)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
1.5mg/g ± 0.5
2.5mg/g ± 1.0
2.0mg/g ± 0.5
2.3mg/g ± 0.6
2.6mg/g ± 0.8
2.4mg/g ± 0.6
Argentina
Brazil
Canada
India
US
MISC
Origin

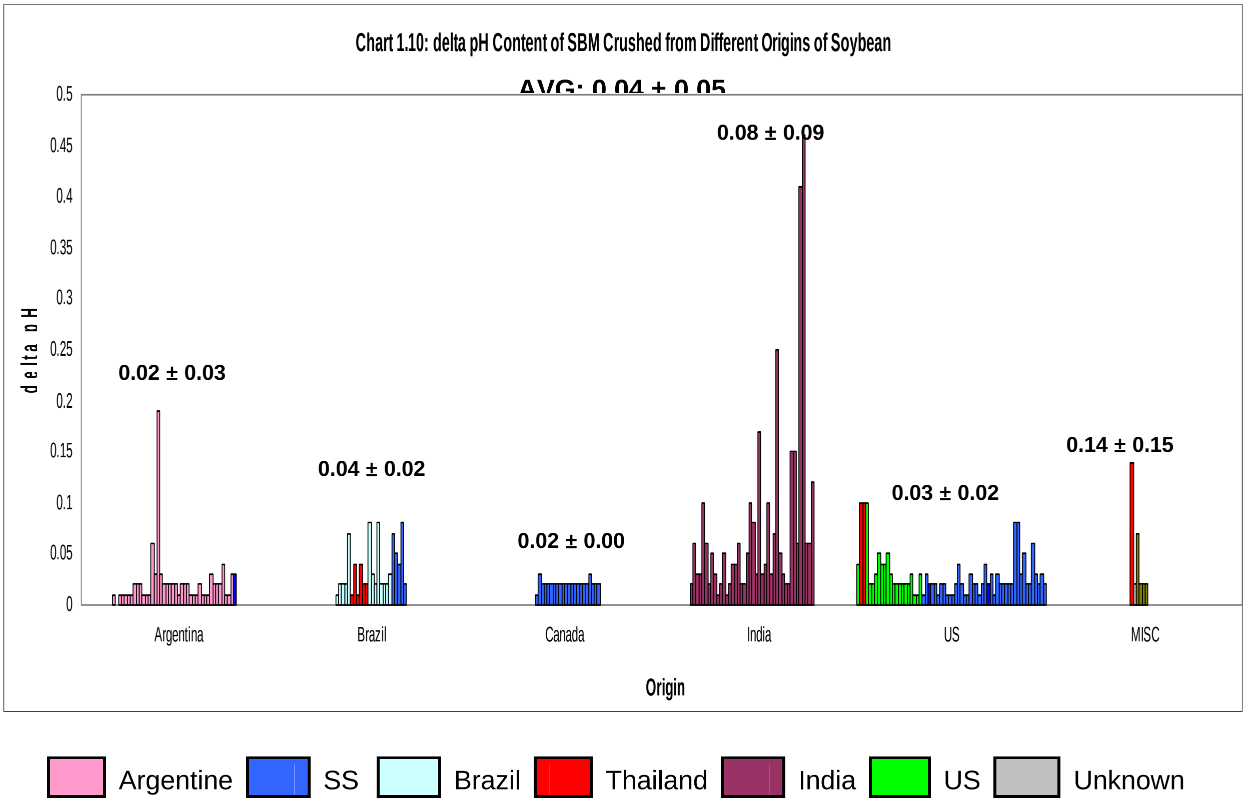


Chart 1.10: delta pH Content of SBM Crushed from Different Origins of Soybean
AVG: 0.04 ± 0.05
delta pH
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.02 ± 0.03
0.04 ± 0.02
0.02 ± 0.00
0.08 ± 0.09
0.03 ± 0.02
0.14 ± 0.15
Argentina
Brazil
Canada
India
US
MISC
Origin
Argentine
SS
Brazil
Thailand
India
US
Unknown

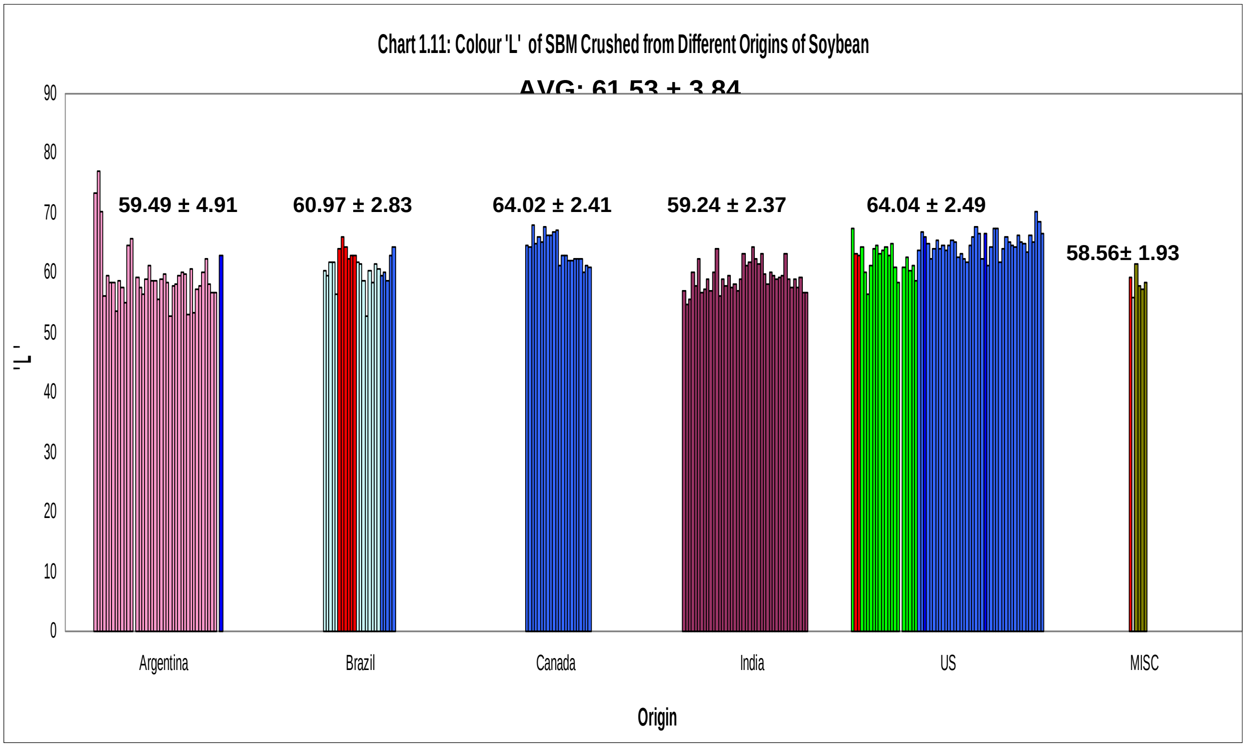


Chart 1.11: Colour 'L' of SBM Crushed from Different Origins of Soybean
AVG: 61.53 ± 3.84
'L'
90
80
70
60
50
40
30
20
10
0
59.49 ± 4.91
60.97 ± 2.83
64.02 ± 2.41
59.24 ± 2.37
64.04 ± 2.49
58.56± 1.93
Argentina
Brazil
Canada
India
US
MISC
Origin

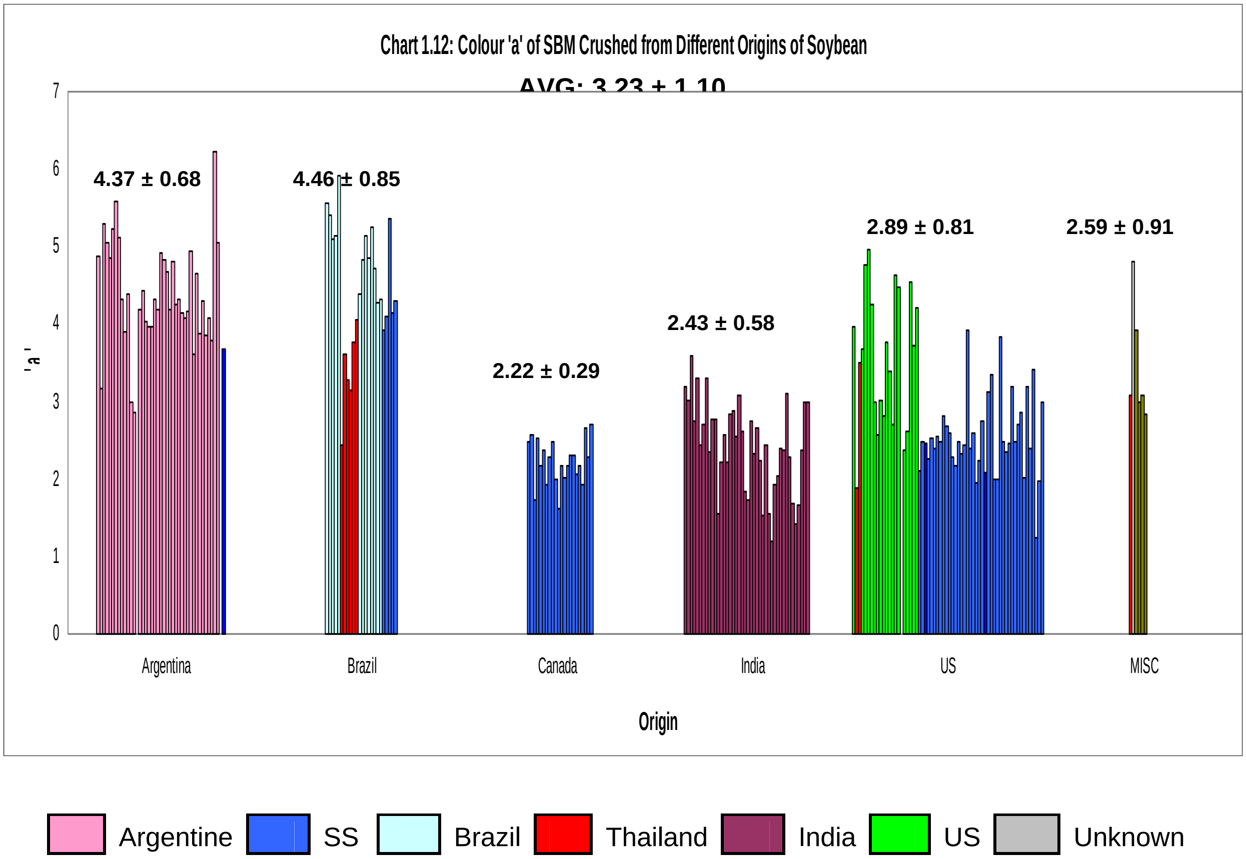
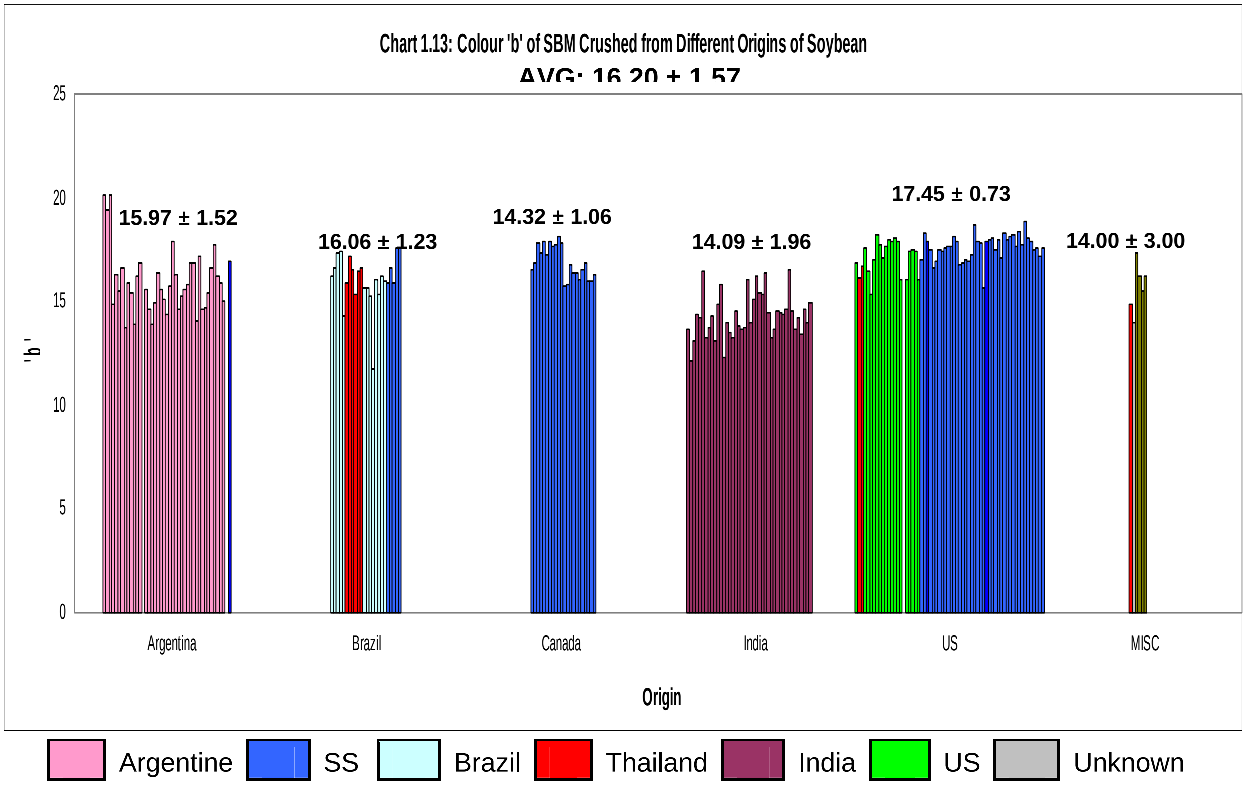


Chart 1.12: Colour 'a' of SBM Crushed from Different Origins of Soybean
AVG: 3.23 ± 1.10
4.37 ± 0.68
4.46 ± 0.85
2.22 ± 0.29
2.43 ± 0.58
2.89 ± 0.81
2.59 ± 0.91
'a'
0
1
2
3
4
5
6
7
Argentina
Brazil
Canada
India
US
MISC
Origin
Argentine
SS
Brazil
Thailand
India
US
Unknown



Conclusions:

Results for the Soon Soon ASAIM soybean meal NIR project have shown a high degree of success, with most parameters showing high RSQ values and low SEP (<0.5).

Furthermore this project provides useful information about the quality of soybean meals from different origins and different crushers.

Feed millers and soybean crushers should find this information very useful. They can approach the American Soybean Association, Singapore or Soon Soon Oilmills, Malaysia if they wish to implement these NIR calibrations in their company.

Acknowledgement

We acknowledge the financial support provided by The American Soybean Association, Singapore for this project and the assistance of the American Soybean Association in helping with sample collection throughout Asia.

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Table 3: Soybean meals quality distribution based on origin.

		Moisture%	PDI%	KOHPS%	Protein%	Oil%	Ash%	CF%	NDF%	TIA(mg/g)	Delta pH	L	a	b	P% @ M12,O1
ALL	Min	9.7	10.2	67.3	42.5	0.38	5.49	1.6	5	0.8	0.01	52.66	1.2	11.74	42.8
	Max	14.2	56.6	92	49.9	3.71	8.89	8.6	16.9	4.5	0.46	77.05	6.23	20.14	50.7
	AVG	11.60	30.06	82.39	46.44	1.77	6.64	3.81	8.47	2.21	0.04	61.53	3.23	16.20	46.6
	STDEV	0.81	10.25	4.48	1.21	0.66	0.69	1.40	2.27	0.79	0.05	3.84	1.10	1.57	1.34
ARGENTINE	Min	10	11.5	72.8	43.2	1.34	5.85	2.5	5.4	0.8	0.01	52.84	2.86	13.75	43.6
	Max	14.2	35.8	89.3	48.2	2.98	7.36	5.9	10.8	3.7	0.19	77.05	6.23	20.14	49.4
	AVG	11.37	22.13	80.34	46.14	2.04	6.57	3.10	7.46	1.52	0.02	59.49	4.37	15.97	46.4
	STDEV	0.81	5.80	3.90	0.77	0.34	0.33	0.70	0.99	0.53	0.03	4.91	0.68	1.52	0.82
BRAZIL	Min	10.6	13.7	67.3	44.4	0.61	5.74	2.2	5.2	0.8	0.01	52.66	2.43	11.74	44.0
	Max	13.4	30.6	88.1	49.9	3.4	6.71	6.1	13.5	4.5	0.08	65.91	5.91	17.61	50.7
	AVG	11.69	21.99	78.92	47.40	1.72	6.24	3.83	8.42	2.48	0.04	60.97	4.46	16.06	47.6
	STDEV	0.61	5.50	5.83	1.49	0.62	0.25	1.11	1.89	1.03	0.02	2.83	0.85	1.23	1.73
CANADA	Min	11.1	32	75.6	44.7	0.89	5.49	1.6	5	1.5	0.01	59.98	1.61	12.17	44.6
	Max	13.5	51.1	89.1	48.1	2.89	6.06	3.3	9.8	3.3	0.03	67.89	2.71	16.52	48.5
	AVG	12.03	41.91	82.32	46.80	1.68	5.83	2.75	7.77	2.00	0.02	64.02	2.22	14.32	47.2
	STDEV	0.64	4.91	3.92	0.97	0.56	0.18	0.39	1.07	0.52	0.00	2.41	0.29	1.06	1.14
INDIA	Min	10	14.7	76.1	43	0.38	6.35	3.6	7.8	1.4	0.01	54.85	1.2	3.65	42.8
	Max	14	56.6	91.7	49.2	2.36	8.89	8.6	16.9	3.8	0.46	64.39	3.58	16.52	48.2
	AVG	11.80	34.46	84.05	45.73	1.10	7.62	5.99	11.83	2.28	0.08	59.24	2.43	14.09	45.7
	STDEV	0.86	9.94	3.54	1.30	0.35	0.68	0.96	1.77	0.61	0.09	2.37	0.58	1.96	1.26
US	Min	9.7	10.2	72.8	44.6	0.51	5.65	2	5	1.2	0.01	56.51	1.24	15.31	43.8
	Max	13.1	52.9	92	49.3	3.71	7.35	5.8	11.4	4.5	0.1	70.23	4.97	18.82	50.0
	AVG	11.36	30.73	84.16	46.76	2.12	6.56	3.16	7.04	2.57	0.03	64.04	2.89	17.45	47.0
	STDEV	0.72	8.75	3.73	0.82	0.66	0.36	0.60	1.05	0.77	0.02	2.49	0.81	0.73	0.99
CHINA	Min	11	30.5	75.4	42.5	0.71	5.68	4.4	9.4	2.2	0.02	57.15	2.83	15.46	42.8
	Max	13.6	50.5	85.6	45.5	1.23	5.86	4.9	11.6	2.6	0.07	61.57	3.93	17.31	45.1
	AVG	12.78	45.18	81.18	43.98	1.05	5.80	4.65	10.53	2.40	0.03	58.68	3.21	16	44.4
	STDEV	1.23	9.80	4.96	1.23	0.24	0.08	0.24	1.04	0.16	0.03	1.98	0.49	1	1
MISC	Min	10.9	21	78.9	43.5	0.56	5.96	3.3	8	1.6	0.02	55.78	1.41	3.65	42.8
	Max	13.1	56.6	91.7	47.4	2.36	8.89	7.1	13.9	3.5	0.46	63.22	4.81	16.52	47.9
	AVG	12.03	36.78	82.73	45.63	1.21	7.51	5.66	11.69	2.39	0.14	58.56	2.59	14	45.4
	STDEV	0.65	11.78	3.67	1.29	0.53	0.87	0.91	1.57	0.58	0.15	1.93	0.91	3	1