Key drivers of quality of soybean products for feed use in South Africa

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Executive Summary

Over the past 10 years (2010-2020), the area under soybean plantings in South Africa has more than doubled, and production has increased by 76 %. The livestock industry in South Africa consumes an estimated 1.2 million tonnes of soybean meal per annum or 98 % of current domestic soybean production (including full-fat soya). Figure 1 provides a spatial distribution of South Africa's soybean production, storage, crushing and feed mill locations.

Over the past few years, there has been a slow but steady trend within the local feed industry from imported to domestically produced soybean meal. The industry, however, requires a reliable, consistent supply of soybean meal from the seed crushers that meets stringent quality characteristics relating to oil and protein (amino acid) content as well as the digestibility of proteins and amino acids (quality of soybean meal). A concern within the feed industry is that the quality of locally produced soybean meal may not yet be as good as that of imported meals. The cost of local supply is an additional consideration here, where soybean production and processing capacity is concentrated in the northern summer production regions and significant feed production capacity is situated in coastal regions (Figure 1) where imported soybean meal could be sourced at a lower cost.

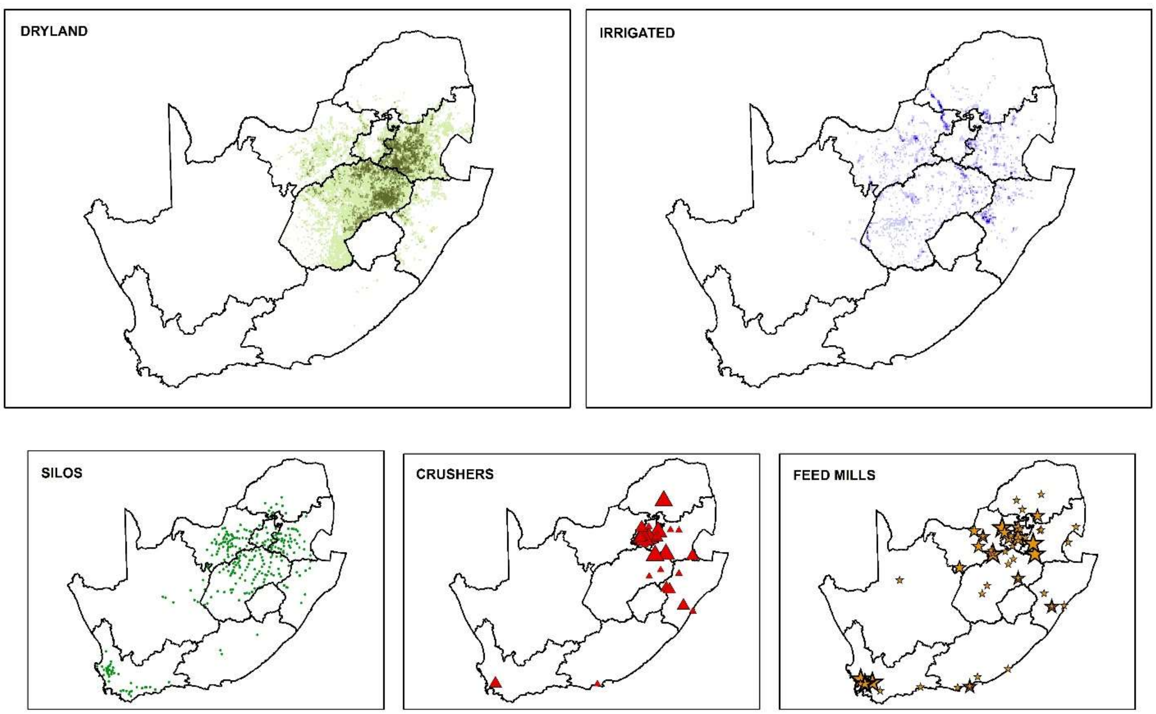

Figure 1: Soybean production, storage, crusher and feed mill locations in South Africa

Soybean quality in South Africa

While approximately 60 % of the value of soybean comes from its meal, the remaining 40 % comes from its oil (Pettersson and Pontoppidan 2013). Therefore, the combined content of protein and oil in soybean seed is more important than just its protein or oil content. The feed industry requires a minimum of 46 % protein in soybean meal (with 12% moisture content) to ensure that the feeds produced by the Industry conform to the Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act (No. 36 of 1947). Shifting the focus from increasing yield per hectare to improved nutrient yield and preserving quality during processing could benefit everyone in the soybean supply chain, from the farmer, silo owner and crusher to the feed/food manufacturer.

The main characteristics that determine soybean quality are low and uniform moisture content, low percentage of foreign material, discolouration, susceptibility to breakage, damage by heat (internal cracks), insect and fungal damage, elevated values of density, oil and protein concentration, and seed viability. Some factors that can affect these characteristics are environmental conditions during the grain formation of plants, season, harvesting system, storage techniques and transport (Briedenhann, 2015). In this study, the effect of agronomic, environmental and crop management factors on soybean quality were investigated. Problems associated with the storage of seed and the factors that influence soybean meal quality during soybean processing (crushing) were unpacked. A thorough literature review was combined with extensive industry interviews and BFAP's economic models to quantify the impact of soybean and meal quality on the South African feed and soybean processing industries.

Soybean composition establishes the limits for soybean meal composition, i.e. protein and oil content of the soybean itself sets the bound for the protein content of the finished soybean meal. Table 1 provides a high-level summary from literature of agronomic factors that have been found to influence protein and oil content of soybeans. The majority "vote" is indicated in the table; however, some contradictory literature was found regarding the effect of planting density.

Table 1: Summary of agronomic factors influencing soybean protein and oil content

	Protein content (number of sources)	Oil content (number of sources)	Report reference
Increased Drought Stress	(4) ↑	(4) ↓	Section 3.1.5, Table 3-4.
Earlier Planting Date	(5) ↓	(7) ↑	Section 3.1.6, Table 3-5.
Increased Planting Density	(3) ↑	(4) ↓	Section 3.1.6, Table 3-6.

In terms of nutrient limiting factors, it was found that Cobalt and Molybdenum (Mo) in alkaline soils increased crop oil content and that combining Nitrogen with Mo positively impacted crop yield and protein content. Higher temperatures increased oil (up to 26°C) and protein content. It was found that early plantings improved seed yield and composition, but not necessarily seed protein content, with optimal planting dates found to be:

- Growth class 6 cultivars early-October
- Growth class 4 to 5 cultivars mid-October

While the majority consensus is indicated in Table 1 above, some contradictory results were found regarding planting density, with few studies having evaluated the effects of the interaction between sowing density and row spacing on soybean chemical composition. It can be concluded that spatial arrangement affects plant structure and morphology, thus affecting oil and protein content.

Unlike some cultivars advertised in Brazil, soybean seed cultivars advertised in South Africa are not accompanied by any information on oil or protein content parameters. Even though the national cultivar trials measure the oil and protein content of the seed, most emphasis is on yield parameters. Breeding for soybean seed composition traits is a complicated process, and to underline this, the major function of protein meal in nutrition is to supply sufficient quantities of essential amino acids – therefore, merely taking soybean protein content into account is likely not enough. However, ample genomic resources and tools are currently available to soybean researchers for the study of seed composition traits (Bandillo *et al.,* 2015; Phansak*et al.,* 2016). It is believed that a combination of conventional breeding strategies and genomic approaches will help to identify genomic loci, haplotypes, and genetic markers aiding inbreeding for improvement of seed composition traits.

Figure 2 compares South Africa's soybean protein and oil content on an as-is (approximately 13 % oil content) basis[1]. Due to South Africa's geographical location in terms of latitude, and its day length and heat unit exposure, the potential oil and protein content is lower than in other countries like the United States, Brazil and Argentina. A study conducted in the United States found a definite trend, with soybean from more northern regions having a higher oil content than southern production regions, but little effect on protein content (Breene, 1988).

The profitability of soybean production is illustrated with the gross margins in Figure 3. Gross margins are off-course sensitive to fluctuations in yield (national average yield is shown): areas with lower input costs often result in lower yields and lower gross margins. In normal years, Mpumalanga performs the best due to higher input costs, higher yield potential and better practices. However, the figure illustrates the potential for North West with its high yields relative to low input costs resulting in high gross margins. This supports the drive to expand soya production in the West. The Free State has a very tight margin in drier years.

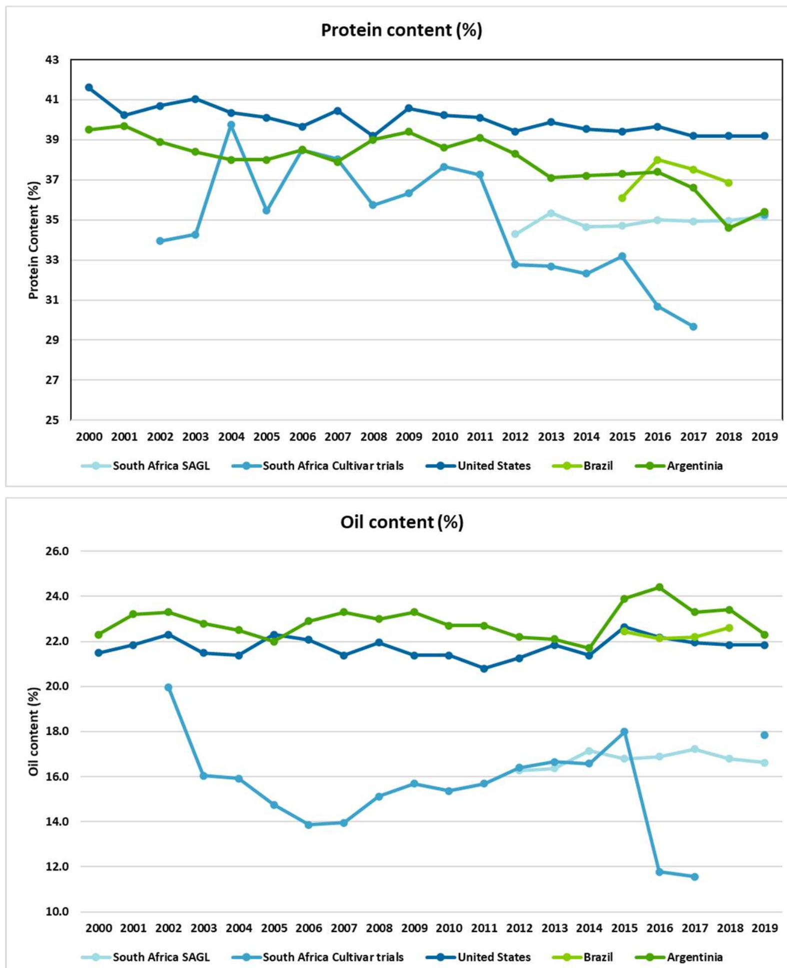

Figure 2: Soybean protein and oil content comparison

[1] To compare the figures it was assumed that the data for Brazil and Argentina are on an "as is" basis, which would roughly equal the 15 % of the United States (moisture content was not stipulated). To compare the data between the countries, South Africa's data, which is published on a dry matter basis, was adjusted to reflect a moisture content of 13 %.

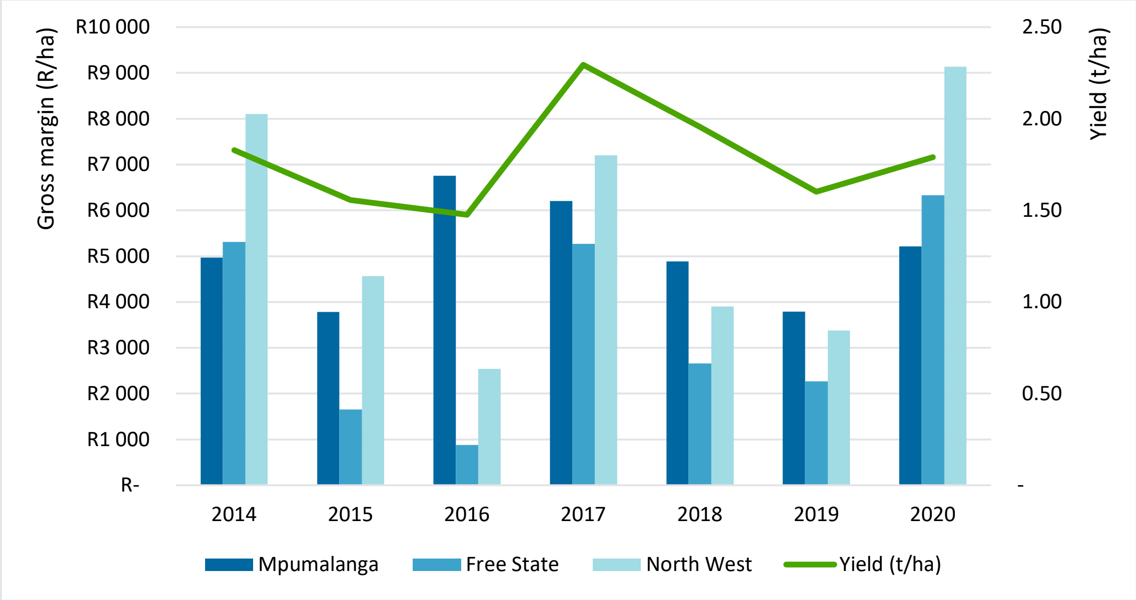

Figure 3 Historic gross margin per main production region

Throughout the period during which soybeans are stored in silos after harvest the main objective is to preserve the characteristics of the grains. It is vital that their quality is preserved (Briedenhann, 2015). The three major factors affecting the quality of soybeans during storage are moisture content, temperature and storage time. Moisture content at delivery is the most important factor for successful storage of soybean seed and should ideally fall between 12 and 14 %. Drying of soybeans is not a common practice in South Africa as yet, however, some farmers have invested in on-farm drying capacity in order to minimise harvest losses and to harvest and deliver their product earlier at higher prices.

South Africa has two grades for soybean seed based only on basic physical aspects. While some silo owners have invested in NIR equipment that could potentially inform on quality aspects of seed such as oil and protein content there is no requirement for these measurements at silo level as yet.

No reference to a quality-based incentive system (e.g. price premiums for higher oil and/or protein content) has been found with reference to the soybean industry either locally or internationally. Furthermore, no adequate grading system is in place to take the graded soybeans further in the value chain. Due to logistical challenges at silos the different soybean seed qualities cannot be kept separate in the downstream value chain.

Soybean processing

In an ideal world, crushers' sourcing strategy would aspire to quality-based sourcing in order to increase efficiencies and profitability of crushing operations. However, South Africa's soybean industry is not yet fully mature and occasionally experiences soybean shortages. This renders a quality-driven sourcing strategy from a crushing perspective impractical in the current market environment. Some crushers have explored the methodology of buying soybeans directly from farms or regions known to have good quality soybeans. This way, they can implement quality control and pay a premium for higher oil and protein levels (e.g., irrigation soybeans). However, this can only be done during the harvest season, as any surplus soybeans are then stored in silos (where they lose their identity) until they are crushed.

Outside of the soybean harvesting season, crushers' sourcing options are significantly constrained and "crushing something" – even if the best-priced available soybean is of sub-optimal quality – is preferrable to "not crushing". Table 2 provides a high-level summary of local and imported soybean characteristics and pricing.

Table 2: Comparing local to imported soybeans

	LOCAL SOYBEANS	IMPORTED SOYBEANS
PROTEIN CONTENT	34 – 38 %	39 – 40 %
OIL CONTENT	14-19 %	→18 % (usually →20 %)
OTHER CONSIDERATIONS	Consensus that yield & protein content have improved, but that there's space for improvement with consistency in protein content. Local seed has a high quality variation w.r.t.: • Growing regions • Between seasons (e.g. drought vs. normal climate) • Within seasons (increasing quality towards end of the season)	Some reports of lower protein & oil content levels and high free fatty acids. Reports of soybeans that were dried resulting in a darker colour and negatively affected oil content.
PRICING (AVERAGE 2019/2020)	R 7 173.06/ton *Local processors report that beans are bought at a discount of R200 – R450 to import parity due to supply and demand dynamics.	R 7 828.51/ton

Soybeans destined for processing are inevitably of variable quality. Therefore, processors must be prepared to test for this variability (most do so using NIR technology) and to adjust their processing practices accordingly. Soybeans are tested for moisture, crude fibre, crude protein and oil content.

Full-fat soya, expeller- and solvent-extracted soybean meal are three completely different products that are not interchangeable. Full-fat soya is an energy and protein source (containing all the oil originally in the bean) while expeller meal is a source of protein only (most of the oil has been extracted). Expeller soybean meal, also called extruded meal, is a midway product where some of the oil has been extruded, but the result is less energy-dense than full-fat soya and lower in oil and protein than solvent meal (see Table 3). Solvent extracted meal has been through an expeller type process and further processed with a solvent to remove most of the oil.

Table 3: Solvent meal vs expeller meal vs full-fat soya

	Protein content	Oil content	Fibre
Solvent soybean meal	46.5 %	2 %	Max 4 %
Expeller soybean meal	42.5 – 43.5 %	5 - 7 %	Max 6 %
Full-fat soybean meal	36 – 37.5 %	15 - 18 %	Max 6.5 %

Source: Industry interviews

In South Africa the majority of soybeans are currently processed by solvent extraction to remove about 99% of the oil content. Soybean meal, the by-product of the process, is included in the diets of most farm animal species (see Figure 4). The majority of soybean meal produced is consumed by poultry followed by the swine, beef, dairy, pet food and aquaculture industries.

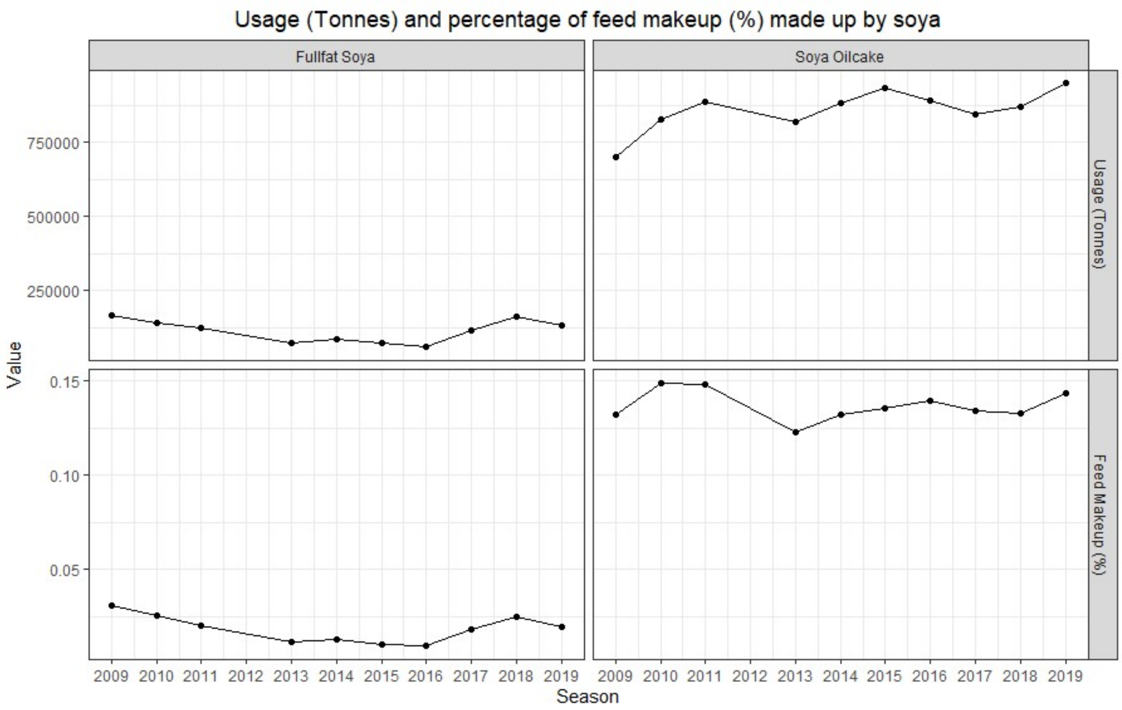

Figure 4: Soybean meal vs. full-fat soya use in South Africa

Most South African feed mills prefer solvent extracted soybean meal and add their oil separately as an energy source, as they can then control the energy and protein levels and their associated costs. However, some feed mills cannot add oil separately during their milling process because they do not have an oil application system and need to use full-fat soybean meal. Full-fat soya is traditionally not as popular because it is often more expensive and feed mills struggle to find reliable, sufficient, good quality suppliers (full-fat crushing plants typically process between 5 000 and 50 000 tonnes per annum which is a lot smaller scale than the 50 000 – 600 000 tonnes per annum processed in solvent plants). Nevertheless, there are feed mills that include full-fat soya and expeller meal in their feed formulation and have come to prefer it to regular soybean meal, due to its energy contribution. It was regarded as an efficient substitute for fishmeal. Local expeller soybean meal is also favoured due to its consistent low urease reading of between 0.03 – 0.05. In the following sections, the definition and measurement of soybean meal quality will be discussed.

Crushing margins are very tight and volatile (see Figure 5). A slight decrease in oil or meal prices, or increase in soybean cost, may result in crushers making a loss. The varying gross margins offset each other, one year's profit compensating for the next year's loss. Crushers generally make a smaller gross margin in the years where either South Africa or America experienced a dry year, and fewer soybeans are available. The volatility extends within the years, as the harvest comes in and stocks increase and decrease.

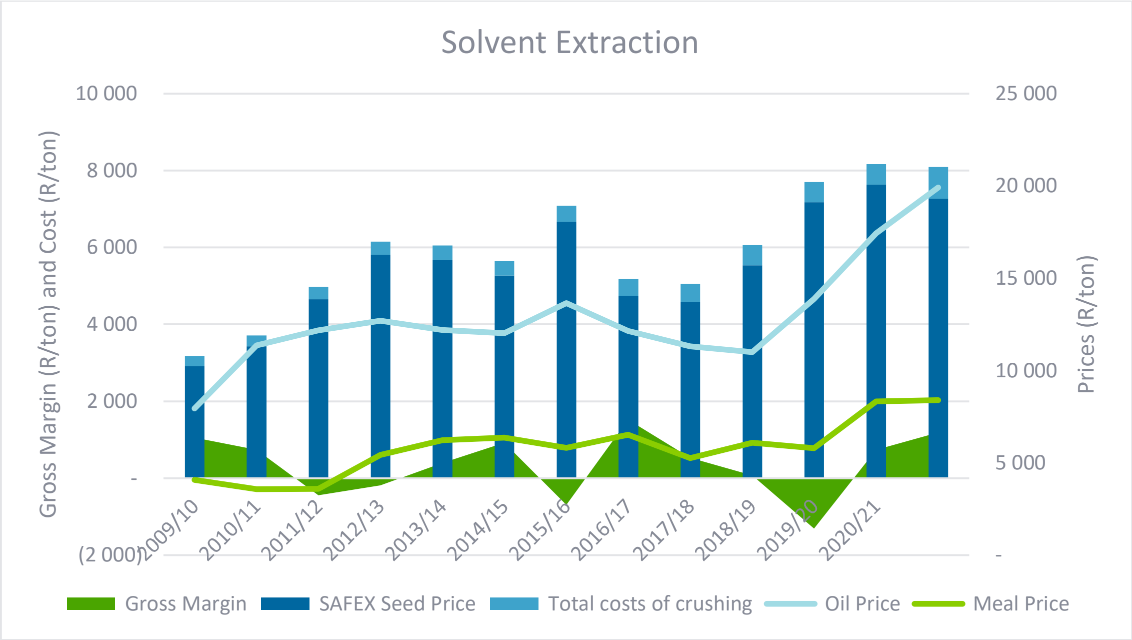

Figure 5: Solvent crushing margin

Soybean meal quality

Soybean composition establishes the limits for soybean meal composition (a better quality bean results in a better quality meal), while processing ultimately determines meal composition within these limits (processing needs to run without fault to comply with specifications).

The processor greatly contributes to the nutritional value of meal by reducing the bioactivity of anti-nutritional soybean proteins through the proper use of heat during "toasting". The challenge with toasting is that sufficient heat must be applied to the de-oiled meal to denature the anti-nutritional proteins thereby rendering them biologically inactive, but not to the extent that the soybeans are overheated resulting in a lower digestibility of the protein. A number of factors must be continuously managed to achieve consistently the proper toasting "sweet spot", including the combination of

- Heating time and
- Heating temperature.

Table 4 defines under- and over-processing of soybean meal and lists the negative effects of both on poultry production. Soybean crushers and feed manufacturers need reliable methods to differentiate between good quality soybean meal and under- or over-processed meal, to mitigate these negative effects well. The following section discusses the various tests used to determine whether soybean meal is under- or over-processed.

Table 4: Under- vs. Over-processing of soybean meal

	NEGATIVE EFFECTS OF UNDER-PROCESSING	NEGATIVE EFFECTS OF OVER-PROCESSING
DESCRIPTION / DEFINITION	Occurs if i) the process of heating is completed too rapidly or ii) if the temperature at which the meal is processed is too low. The anti-nutritional factors are not destroyed, and this leads to a reduction in amino acid digestibility	Occurs when proteins are exposed to excessive heat treatment. The proteins are denatured, and amino acid digestibility is reduced; the negative effects that cause reduced analytical concentrations and reduced digestibility of amino acids occur for lysine and cystine.
NEGATIVE EFFECTS:	• Proteolytic enzyme activity is inhibited, decreasing digestive efficiency. • Pancreatic hypertrophy. As a consequence of inhibition of proteolytic enzymes, the animal reacts to the presence of protease inhibitors by secreting more digestive enzymes, which results in pancreatic hypertrophy. • Increased demand for vitamin D. • Diarrhoea results because the lectins (haemagglutinins) present in under-processed soybean meal destroy the intestinal mucosa. • Nutrient absorption is reduced as a consequence of injury to the mucosa and inhibition of proteolytic enzymes. • Decreased bird performance will occur, especially among young birds	• Decreased quality of protein. • Decrease in the true amino acid digestibility of certain amino acids (lysine, and to a lesser extent cystine and arginine). The effects on lysine can largely be explained by the Maillard reaction in which free amino groups are bound to free carbonyl groups (e.g., reducing sugars or carbohydrates). • Possible reduction of choline contents (unclear) • Reduced performance of growing chicks.

Testing for under- or over-processed soybean meal:

In vivo monogastric animal growth performance testing is seen as the most relevant means of assessing soybean meal quality. However, such a direct analysis is challenging and impractical in routine operations. These types of trials are not only extremely costly and time consuming, but *in vivo* animal testing also requires many ethical considerations (Festing and Altman, 2002). Fortunately, there are several *in vitro* tests (also referred to as wet-chemistry or laboratory analysis) available to assess soybean meal quality. However, there is no single test available that can assess both under- and over-processing of soybean meal.

The following tests are most widely used to evaluate soybean meal quality:

- **Urease activity** (UA, American Oil Chemists Society, 2000). The presence of active trypsin can be indirectly determined by measuring the activity of urease enzyme present in soya. Both trypsin inhibitor and urease proteins are denatured and deactivated during heating. Urease, unlike trypsin inhibitors, is easy to measure, and is therefore used as a marker of trypsin inhibitor activity. **Although the urease test is routinely performed and often used in contract specifications, the results do not correlate well with animal performance.**
- **Protein Dispersibility Index (PDI)** (PDI, Batal *et al.,* 2000). PDI is useful to further distinguish the quality of soybean meal that is otherwise considered to be of good quality based on the urease and KOH measurements. **A PDI between 45 and 50 % and urease of 0.3 pH unit change or below indicates that the soybean meal is of extremely high quality, adequately heat processed but not over-toasted.**
- **KOH** protein solubility (KOH, Araba and Dale, 1990 a, b; Parsons *et al.,* 1991). Protein solubility in 0.2 % KOH has been shown to be a good indicator of *in vivo* protein quality for overprocessed soybean meal. **Samples with high KOH values are most digestible as long as urease activity is below the upper recommended limit.**
- **Trypsin inhibitor activity** (TIA) (TIA, Kakade *et al.,* 1969; 1974; Hamerstrand *et al.,* 1981). The measurement of the trypsin inhibitor activity (TIA) is not commonly used due to the complexity of the analysis as well as the time required. **Activity levels of between 30 and 40 mg/g of soybean meal indicates raw meal whilst levels lower than 5 mg/g are acceptable for young animals.**

Some of these tests are quick and easy to process, whilst others require skill and reliable laboratory technicians (see Table 5-10). Analysis of quality of soybean meal using *in vitro* techniques has some disadvantages:

- **Repeatability**: Although *in vitro* soybean meal quality test results within laboratories do not differ significantly, those between laboratories differ significantly (de Coca-Sinova *et al.,* 2008).
- Results do not always **correlate with the intensity of the heat processing** (de Coca-Sinova *et al.,* 2008). Thus, various research studies have proven *in vitro* analysis of soybean meal quality to be a poor indicator of soybean meal quality (Palić and Grove, 2004; Caprita *et al.,* 2010b; Palić *et al.,* 2008 and Palić *et al.,* 2011).
- Furthermore, **the tests may not be correlated with actual animal performance.** Of the available *in vitro* tests, it has been shown that TIA is the best predictor of i*n vivo* efficacy for soybean meal (de Coca-Sinova *et al.,* 2008; Ruiz, 2012a; Ruiz and de Belalcazar, 2017; Ravindran *et al.,* 2014). However, the TIA test is tedious and time-consuming and, as mentioned in the previous point, may still provide inconsistent results because of **differences in methodology among laboratories** (Sueiro *et al.,* 2015; Chen *et al.,* 2020).

It is thus essential that feed formulators consider various quality indicators jointly in order to make inference about the quality of the soybean meal. In South Africa, most feed formulators make use of *in vitro* analysis to assess soybean meal quality. Table 4-5 presents a summary of suitability for under- or over processing. For more detail on each test refer to section 5.9.1 and Table 5-10.

Some believe that the combination of the KOH and PDI tests gives the best representation of the soybean processing quality. Stakeholders in the industry disagree on which test is the best to use but agree that a single test is not adequate, preferring to conduct a combination of tests to get reliable results which unfortunately has a cost and time associated with it. Many feed mills have an ad-hoc system, where not all tests are conducted on all loads, but rather a tendency is determined for future discussions and as reference for possible price negotiations.

Table 5: Chemical analysis methods for processed soybeans. Source Fryer (2016; 2020)

	Urease activity	PDI	KOH	TIA	Reactive lysine: Total lysine
Under processing	+++	++	+	+++	No
Over processing	No	+	++	No	+++
Target values	< 0,3 pH rise < 0,4 mg N/g*min	15 to 40 %	73 to 85 %	< 4 mg/g	> 90 %
Ease of use	Most common	Simple method	Simple method	Difficult	Difficult

Suitability rating
+++ high
++ medium
+ low

Figure 6 illustrates the possible quality tests and decision outcomes of the meal quality measuring process at crushers and feed mills. Important to note, is that each crusher and feed mill is different and conducts a combination of different quality tests and may have extra rules and regulations resulting in an option being unviable.

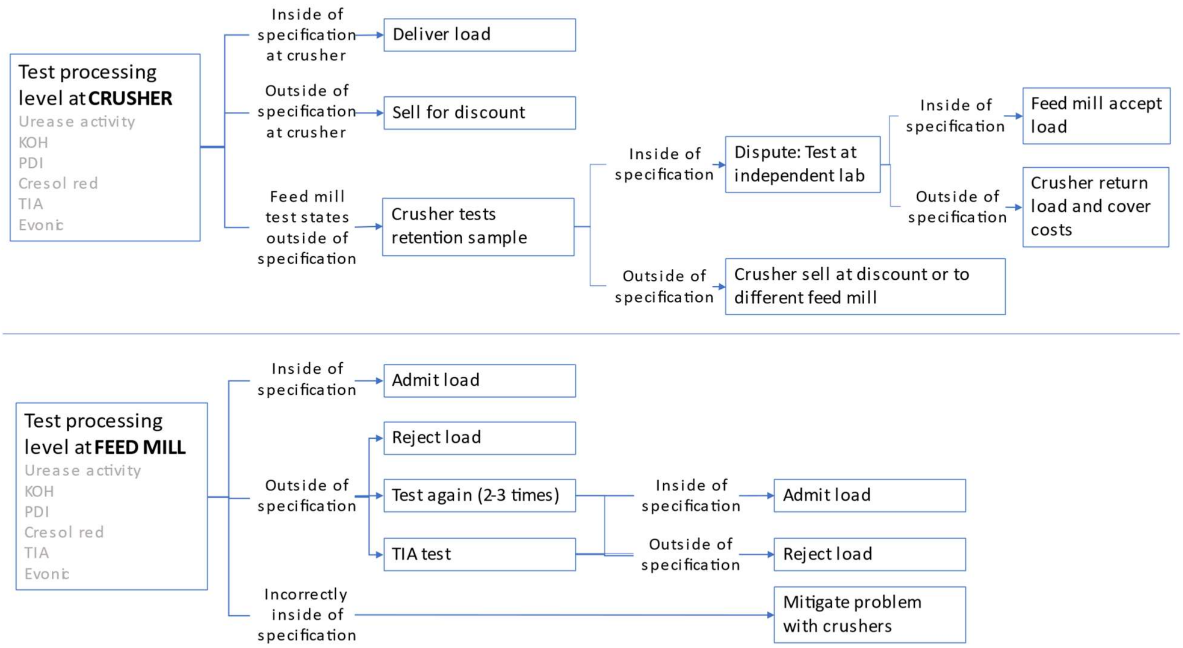

Figure 6: Meal processing quality measuring process

Occasionally, crushers discount their meal price due to seasonal over-supply in the market and historically, discounts driven by sub-quality product were negotiated with off-takers (this is reportedly not commonly practiced anymore). Figure 7 illustrates the effect that different discount levels can have on the gross margin of crusher. Crushers still need to incur the same variable costs but receive a lower price for their meal. They make R72 less profit per 1 % discount that they give. At a 5 % discount, this accumulates to R361 per ton.

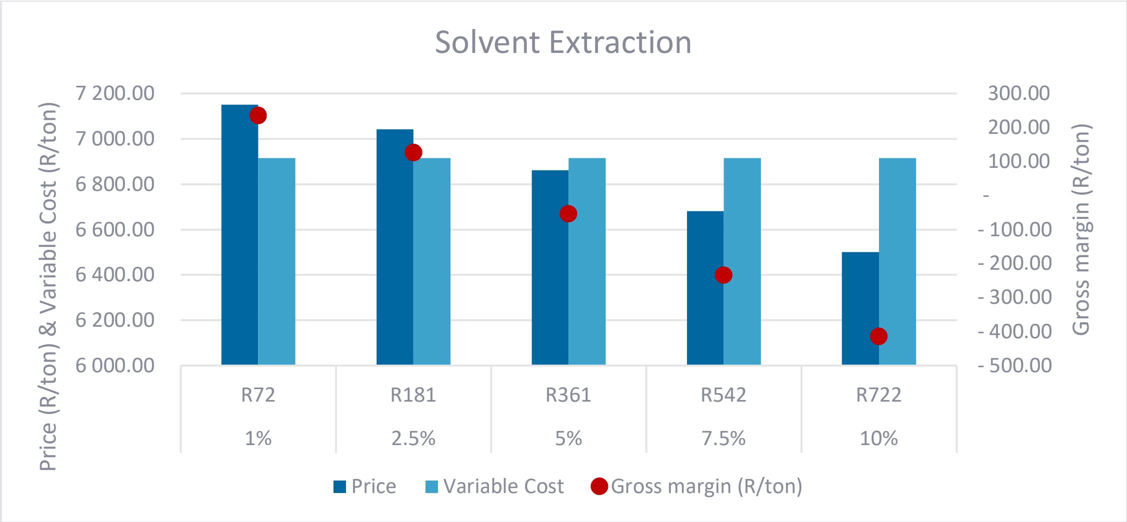

Figure 7: Crushing margin sensitivity to price discounts

Soybean meal comparisons and standards

International soybean meal quality comparisons indicated that the composition of soybean seed and soybean meal varied depending on the country of origin and where they were processed. When soybean meals subjectively deemed to be of low, intermediate, and high qualities were evaluated, amino acid concentrations and protein solubility in KOH tended to improve as subjective quality increased. Other conclusions include:

- At similar crude protein contents, the nutritive value of soybean meal is greater for the United States meals than for the South America or Indian meals.
- United States meals have less crude protein and fibre and more sucrose, phosphorus, and indispensable amino acids per unit of protein than Brazilian meals.
- The differences observed in nutritive value of the soybean meal depend not only on the processing conditions applied by the crushing plant but also on the origin of the soybeans.
- Nutritionists should use different matrices to describe the nutritional value of soybean meal of different origins.

In recent years there has been an interest in evaluating soybean meals sourced internationally with those of locally produced meals from different processors. These trials focussed only on monogastric nutrition. Most of the soybean meal that has been imported to South Africa for the last 20 years has been produced by Molinos in Argentina, this meal having maintained a very high quality, delivering excellent animal performance and, as such, has been historically regarded to be the "gold standard" in South Africa.

Four trials have been published that compare imported to locally produced soybean meal:

- Briedenhann (2016) presented results of an independent trial comparing four locally produced meals to that of Argentinian imports.
- Gous (2018) compared the performance of three South African soybean meals to that of imported meal originating from Molinos crushers in Argentina.
- Barnard (2018) evaluated a similar imported soybean meal from Argentina to locally produced meal that was produced during a day shift at a crusher, a night shift at a crusher and under processed soybean meal.
- Cronje (2019) evaluated *in vitro* quality parameters and digestibility between locally produced and imported soybean meal from Argentina destined for the South African pig industry.

All these trials concluded that locally produced soybean meal is not inferior to imported meal based on proximate analysis and quality tests. Table 6 summarises the trial outcomes, and suggests that although the South African soybean meal was of acceptable quality, the variation in processing quality parameters was higher for local soybean meal than for the imported meal (in accordance with some industry reports).

Table 6: Comparing local and Argentinean soybean meal

<table>
<tr><th></th><th></th><th>LOCAL MEAL</th><th>IMPORTED MEAL (ARGENTINA)</th></tr>
<tr><td rowspan="5">PROXIMATE ANALYSIS (SEE TABLE 6-11 FOR MORE DETAIL)</td><td>Protein (%)</td><td>44.9 – 53.1</td><td>46.1 – 53.5</td></tr>
<tr><td>Fat (%)</td><td>1.3 – 2.5</td><td>0.7 – 1.8</td></tr>
<tr><td>Fibre (%)</td><td>2.8 – 4.7</td><td>3.2 – 4.8</td></tr>
<tr><td>Moisture (%)</td><td>7.3 – 11.7</td><td>7.9 – 11.9</td></tr>
<tr><td>Ash (%)</td><td>5.4 – 6.7</td><td>5.6 – 6.9</td></tr>
<tr><td rowspan="6">PROCESSING QUALITY PARAMETERS (SEE TABLE 6-12 FOR MORE DETAIL)</td><td>TIU/mg</td><td>1.1 – 5.2</td><td>1.3 – 1.6</td></tr>
<tr><td>KOH</td><td>73.6 – 94.3</td><td>74.1 – 83.9</td></tr>
<tr><td>PDI</td><td>9.6 – 25.2</td><td>17.9</td></tr>
<tr><td>Lysine R</td><td>2.5</td><td>2.5</td></tr>
<tr><td>Evonik</td><td>13.0-15.0</td><td>12.0</td></tr>
<tr><td>Urease</td><td>0.02 – 0.51</td><td>0.02 – 0.12</td></tr>
<tr><td colspan="2">PRICING</td><td>R 5 777.64/ton (average 2020)</td><td>R 7 119.65/ton (average 2020)</td></tr>
</table>

Over the past few years, significant work has been done by crushers to improve the crushing process and its delivered product, especially to lower the trypsin inhibitors and deliver a 46.5 % protein meal. The larger crushers seem to be generally comfortable that the process is adhering to output specifications, but this is uncertain when it comes to smaller crushers that struggle to process high moisture content soybeans. Table 7 represents current recommended quality measurements for soybean meal. Currently there are no regulatory mechanisms that police these minimum standards.

Table 7: Recommended quality measurements for soya bean meal. Source: Roosendaal, 2015

Quality Parameter	Minimum standards
Ash	Less than 7.5 %
Acid insoluble ash (silica)	Less than 1 %
Protein solubility index (0.2 % KOH)	75 – 85 %
Protein dispersibility index	15 – 40 %
Urease activity	0,00 – 0,05 pH unit rise
Trypsin inhibitor activity of meal	Less than 3 mg/g
Bulk density	57 – 64 g/100ml
Screen analysis	95 % through a #10 mesh 40 – 50 % through a #20 mesh 6 % maximum through a #80 mesh
Colour	Uniform particle colours of light tan to light brown
Taste	Bland
Contaminants	Free from urea Free from melamine Free of ammonia Free from heavy metals Free from Salmonella

Quality Parameter	Minimum standards
	Free from mycotoxins and mould

There has been a definite shift to using local meal instead of imported meal from Argentina, and buyers seem to be overall satisfied with the current local meal quality. Most feed mills report that protein content of local soybean meal has increased over the past decade and is on par with international soybean meal.

Some stakeholders state that the imported meal from Argentina has better consistency, with set specifications, including processing quality indicators, that are already disclosed when ordering the meal, and a Certificate of Analysis is received upon delivery. Each South African crusher has a different process and preference, resulting in a wider product range. Furthermore, the products of newer plants are reportedly more consistent and can ensure a better-quality product with more accurate tests. Some believe that South African meal has overtaken Argentina meal in terms of quality, and that South Africa produces some of the best soybean meal quality in the world. However, there are still some negative reports, like variation within a load, and local soybean meal being courser than imported meal that needs to be reworked to improve the digestibility.

Similar to crushers, there is consensus on the feed mill side, that if the correct process and procedure is followed during crushing, the meal will conform to quality specifications. Rejections have decreased over the years as crushers have started focusing more on the meal as main product and have incorporated what they have learned about quality requirements in collaboration with their off-takers. There is relatively good transparency, with numerous reports of feed mills working with crushers to ensure that the meal complies with their required specifications. The larger crushers stated that they have had very few rejected loads, and none of them were due to low protein or incorrect processing.

Soybean meal quality mitigation

Processing consistency is the most important factor for feed mills. It is even more important than protein content as there is no proper mitigation for wrongly processed meal at feed mill level, and monogastric animals cannot digest the feed. The crushing industry is a competitive space, and crushers continuously investigate and adjust to solve and mitigate issues. If the protein content of the produced meal is below specification, crushers can blend it with higher protein meal, but only up to a point if the protein content is not too low. This is supposedly done by Argentina to form a constant protein level and consistent meal. Other local crushers stated that blending leads to inconsistent feed, and that the protein content should rather be manipulated with the oil, fibre, and moisture content of the beans. By removing more moisture and fibre in the beans, the protein level is increased.

Feed mills adjust their formulation according to the protein content to ensure they meet their specifications. This can however only be done up to a certain minimum protein level, after which some feed mills reject the load. Some feed mills increase the protein level with other protein sources like sunflower, full-fat soya and canola, or amino acids. This is however very expensive.

Table 8 summarises the potential mitigations that are used by some crushers and feed mills for low protein, incorrect processing levels and meal size. It is important to note that the mitigations are merely views of some stakeholders, and that other stakeholders may be against the possible mitigations or deem them as unnecessary.

Table 8: Potential mitigations for soymeal

PARAMETER	CRUSHER MITIGATION	FEED MILL MITIGATION
PROTEIN	• Dehull beans • Blend meal • Manipulated with the oil, fibre and moisture content of the beans • Sometimes sell for discount	• Adjust formulation • Add other protein source • Add amino acids • Apply for discount
OVER PROCESSED	• Decrease cooking time • De-hull (limited for cold dehulling) • Blend (only small volumes) • Sometimes sell for discount	• Downgrade digestibility and apply for discount and add probiotics • Only see effect later, calculate effect and talk to supplier
UNDER PROCESSED	• Increase cooking time • De-hull (limited for cold dehulling) • Blend (only small volumes) • Re-process bit by bit	• Downgrade digestibility and apply for discount and add probiotics
MEAL SIZE		• Mill again

From a feed formulation perspective, shortcomings in raw materials used in feed formulation such as soybean meal can be corrected to some extent using additives. The most common is the addition of synthetic amino acids, enzymes and pro- and pre-biotics. However, the cost of additives is high and could not realistically be used to mitigate all negative effects of out-of-spec soybean meal quality but would rather be used to enhance the digestibility of feed to lessen some anti-nutritional factors. Table 9 presents a summary of some of the most important anti-nutritional factors in soybeans.

Table 9: Summary of anti-nutrient factors in soybeans. Sources: Liener (1977), Ensminger and Olentine Jr (1978), Peisker (2001)

ANTI-NUTRITIONAL FACTOR	MODE OF ACTION	METHOD OF DETOXIFICATION
PROTEASE INHIBITORS	• Combines with trypsin or chymotrypsin to form an inactive complex and lower protein digestibility • Causes hypertrophy of the pancreas • Counteracts feedback inhibition of pancreatic enzyme secretion by trypsin	• Heat treatment • Germination • Fermentation
LECTINS (PHYTOHAEMAGGLUTININS)	• Agglutinates red blood cells	• Heat treatments
ANTI-VITAMIN FACTORS (RACHITOGENIC FACTOR AND ANTI-VITAMIN B12 FACTOR)	• These factors render certain vitamins (e.g. vitamins A, B12, D, and E) physiologically inactive	• Cooking • Supplementation of vitamins
GOITROGENS	• Enlargement of the thyroid	• Heat treatment in some cases • Administration of iodide

METAL-BINDING FACTORS (PHYTATE)	• These factors decrease availability of certain minerals (e.g., P, Cu, Fe, Mn,Zn)	• Heat treatment • Addition of chelating agents • Use of enzymes
SAPONINS	• Bitter taste, hemolyze red blood cells	• Fermentation
ESTROGENS	• Cause an enlargement of the reproductive tract	
CYANOGENS	• Cause toxicity through the poisonous hydrogen cyanide	• Cooking
OLIGOSACCHARIDES	• Impair digestion (e.g. intestinal cramps, diarrhoea, flatulence)	• Ethanol/water extraction
ANTIGENS (GLYCININ AND B-CONGLYCININ)	• Cause the formation of antibodies in the serum of calves and piglets. Prevent proliferation of beneficial bacteria in the gastrointestinal tract	• Ethanol/water extraction

Perspectives from Feed Mill industry

Figure 5.10 illustrates the profitability of a feed mill that produces an average broiler feed. The main inputs for broiler feed are maize and soybean meal. The specific contribution levels vary per feed mill and feed type. These are also the major costs that feed mills incur.

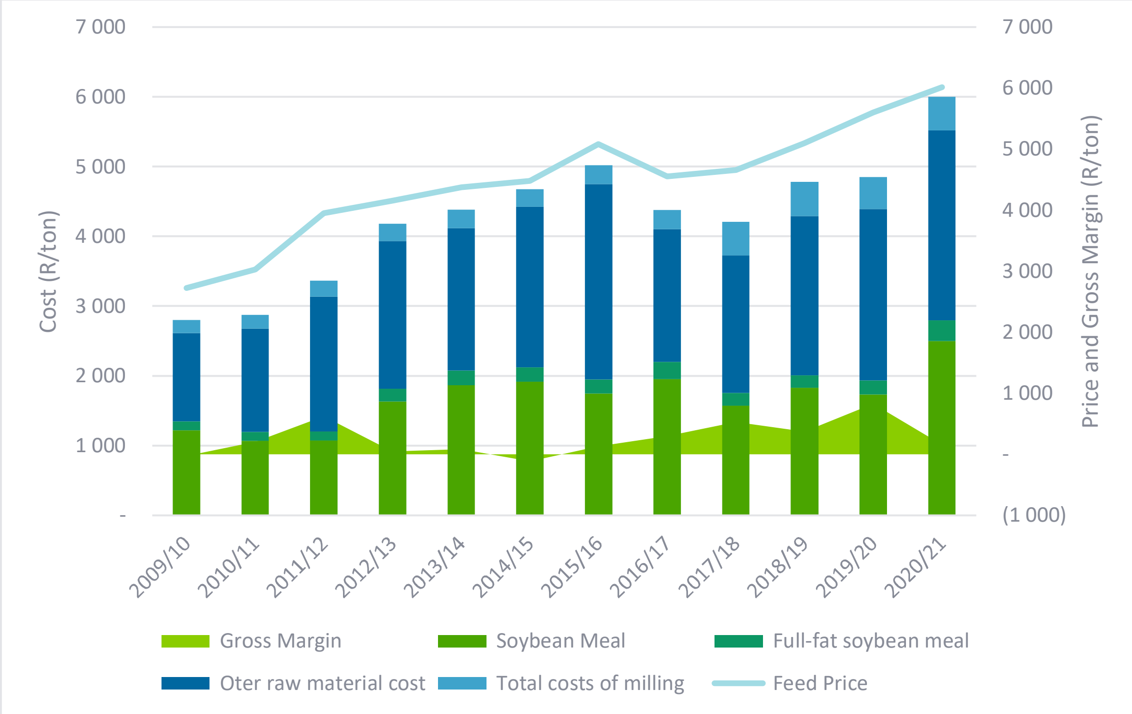

Figure 8: Profitability of a feed mill that produces an average broiler feed

As soybeans are the main protein source, the gross margin is highly dependent on the price of soybean and full-fat soya, because a certain threshold of protein needs to be achieved. As the prices of the inputs vary, feed mills can vary the input contributions. There are however limits to what extent they can adjust the formulation.

Overall, soybean meal has become the preferred protein source for intensive poultry feed formulation (which is the largest feed consumer world-wide), due to the following characteristics:

- Soybean meal contains a high level of protein in comparison to other plant protein sources.
- Soybean meal has an excellent profile of essential amino acids and these amino acids are highly digestible. Soybean meal has the highest lysine digestibility of any of the commonly available protein sources. It also ranks high in methionine, cystine and threonine digestibility. In addition, the variation in digestibility is lower for soybean meal than for other oilseed meals.
- Soybean meal has an excellent lysine to protein ratio.
- Soybean meal is a palatable source of supplemental protein. It does not adversely impact the palatability of feeds for poultry or any other type of livestock.
- Soybean meal can serve as the sole source of supplemental protein for all types of poultry and swine at any stage of growth or production. In most poultry and swine diets soybean meal provides 80 % of the dietary amino acids.
- Generally, soybean meal is a competitively priced source of protein.

Despite these positive aspects and the importance of soybean meal as feed ingredient, the quality and digestibility of soybean meal is vital for the feed mill and poultry industry (as discussed in previous sections). Multiple *in vivo* trials have been conducted by feed industry stakeholders to study the relationship between quality indicators of soybean meal such as Urease, KOH, and PDI on either feed intake, average daily gain and feed conversion ratio which are mainly influenced by the crude protein availability and the amino acid composition. A small gain in digestibility of feed and therefore improved feed efficiency could have a large financial impact for poultry producers.

An objective of these trials was to investigate the feasibility of determining an optimum Urease, KOH and / or PDI within the "in-spec ranges" that achieves maximum feed efficiency. Preliminary results have shown that the impact of optimizing soybean meal quality (i.e. further refining acceptable quality parameter specifications) can lead to increases in final bird weight of between 15 and 50 g for the same days-to-slaughter and total feed consumption. Table 10 demonstrates the impact of these improvements on the implied feed conversion ratio and profits per bird (R/bird or kg).

Table 10: Impact of improvement in final body weight on profit and feed conversion ratio for high- and low-density farmers

Increase in final broiler weight (g)	15	20	25	30	35	40	45	50
High-density Farmer								
Profit gain (%)	2.96	3.91	4.85	5.92	6.86	7.81	8.76	9.7
Implied FCR value	1.44	1.43	1.43	1.43	1.42	1.42	1.41	1.41
Implied FCR improvement	0.69	1.40	1.40	1.40	2.11	2.11	2.84	2.84
Feed cost per kg reduction	0.87	1.12	1.37	1.63	2.01	2.26	2.52	2.78
Low-density Farmer								
Profit gain (%)	3.81	5.02	6.24	7.46	8.68	10.05	11.26	12.48
Implied FCR value	1.6	1.59	1.59	1.59	1.58	1.58	1.57	1.57
Implied FCR improvement	0.63	1.26	1.26	1.26	1.90	1.90	2.55	2.55
Feed cost per kg decrease	0.89	1.12	1.35	1.69	1.92	2.15	2.38	2.73

Further trials to quantify the relationship between quality indicators and poultry production performance are underway and have the potential to further refine industry-wide best practices regarding soybean meal processing quality.