aegic
Australian Export Grains Innovation Centre

Quantifying the true cost of wheat lots

to optimise value for flour mills

INFORMATION PACK

Department of Primary Industries and Regional Development
GOVERNMENT OF WESTERN AUSTRALIA
GRAINS AUSTRALIA

aegic.org.au

AEGIC is an initiative of the Western Australian State Government and Grains Australia

WHA422007EN

Wheat accounts for about 80% of flour production costs[1]. Therefore, wheat selection has a major impact on a mill's financial position.

This information package will explain how to make the best wheat selections by correctly quantifying the financial value of wheat lots. The information is presented with a view to highlighting the potential value advantage of selecting Australian wheat.

This will include two parts:

1. **Australian wheat overview** — a brief overview of Australian wheat including the industry, the wheat itself and some tips on how to mill it.
2. **Quantifying wheat value** — an explanation of how to quantify the financial value of wheat lots.

We will explain how choosing high quality wheat, such as Australian wheat, though sometimes more expensive per tonne of raw wheat purchased, can actually result in significant savings when compared to milling cheaper low-quality wheats. The information presented here has the potential for significant savings every year.

Contents

Part 1. Australian wheat overview

Key point: Australian milling wheat is high quality. It is clean, dry, white and hard, providing many milling advantages. The Australian wheat industry has well established systems to aid you with good wheat selection.

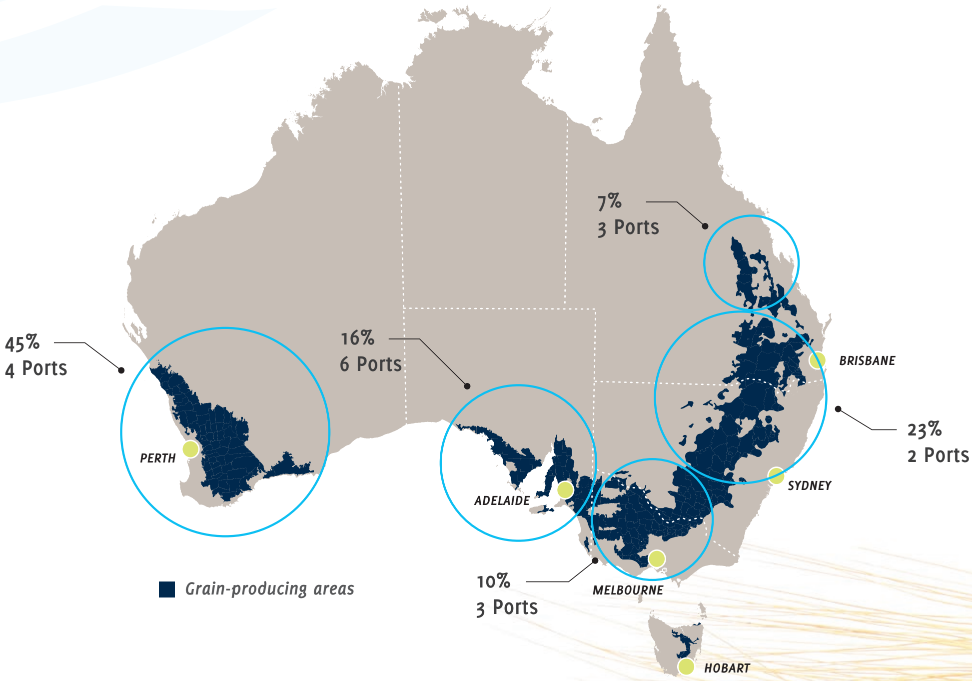


Figure 1. *Map of the Australian wheatbelt with the number of export ports and the percentage of average production shipped through those ports.* Source AWB

The Australian wheat industry

The Australian wheat classification system is overseen by Grains Australia. The Grains Australia Wheat Council is responsible for the Wheat Variety Classification Framework and the evaluation of wheat applications is carried out by the Wheat Variety Classification Panel (WVCP), an independent sub-committee of the Grains Australia Wheat Council.

When receiving wheat, grain handlers assign wheat lots to grades based on the quality characteristics of that lot under the grading standards set out by Grain Trade Australia (GTA)[2]. The trading and handling of grain is conducted by a range of companies, the biggest of which are CBH in Western Australia, GrainCorp in the eastern states of Australia and Glencore/Viterra in South Australia. These companies operate sophisticated storage and transport to maintain grain hygiene and grade integrity.

Australian wheat: high quality

Wheat supplies in Australia are predicted to be plentiful this season.[3] Australian wheat is known for being high quality; low in microbial and fungal contamination, low in screenings, low in moisture and reliably classified into quality-dependant grades for sale.

The major milling grades and the foods they are used for are summarised in Table 1 below.

Table 1. Australian wheat grades and their uses

Australian wheat grades	Uses
Australian Prime Hard (APH)	Yellow alkaline noodles (YAN), pan breads
Australian Hard (AH)	Breads (flat and western), YAN (medium)
Australian Premium White (APW)	Asian noodles, Middle East breads
Australian Standard White (ASW)	Middle East breads, steamed buns, instant noodles
Australian Noodle Varieties (ANW, APWN)	White salted noodles (udon)
General Purpose	Gristing
Australian Soft	Biscuits, cakes, pastries, steamed buns, snack foods
Durum	Pasta, spaghetti
Feed	Livestock rations

Milling tips

Milling Australian wheat should take into account that it is often clean, white, dry and hard, although there are also Australian soft wheat classes.

The following is a 'how to' list for milling Australian wheat:

How to store:

The cleanliness and low moisture content of most Australian wheat should increase the length of time it can be safely stored. The maximum allowable moisture content for Australian wheat is 12.5%[4]. Most Australian wheat will be traded well below 12.5%. As an indication of what to expect, see Appendix 1.

Some other exporting countries allow moistures up to 14.5%[6]. The graph below is a rough guide showing the impact that changes in moisture content above 12% can make to safe storage times [7]. For example, for grain stored at 32°C, the safe storage time is about 130 days at 12% moisture but only about 30 days at 13% moisture, a difference of 100 days. The difference at 21°C is about 300 days.

How to blend:

This is covered more fully in Part 2, however it is worth noting that although high protein AH or APH wheat is often useful for boosting the protein in a grist, sometimes using 100% APW in a grist can represent better value than blending a high protein wheat with a cheaper base wheat.

How to clean:

Since Australian wheat is relatively clean the miller should consider increasing screenroom throughput. The major Australian milling grades do not allow screenings above 5%[4], and the actual screenings levels are usually well below that. As an indication of what to expect, see Appendix 1.

A possible defect of Australian wheat is 'black tip'. This is a dark discolouration on the bran surface and is a reaction by the wheat plant to stress during the growing season. It is not a microbial or fungal contamination and does not affect the endosperm. It will be removed with the bran and germ. Major milling grades do not allow more than 5% of grains to be affected by black tip[4]. Colour sorters can be used to remove these if desired.

Figure 2. ***Effect of wheat moisture on safe storage times***

Figure 3. ***Black tip***

How to condition:

Since Australian wheat is relatively dry (moistures can get as low as 8%) larger quantities of water may need to be added when conditioning prior to milling. The low moisture content has storage advantages and the extra moisture added during conditioning can lead to high flour yields relative to dry wheat weight (discussed in more detail later). Low moisture wheat may require longer tempering times and multi-stage conditioning. The hardness of some Australian wheat can also increase the target moistures needed, and also further increase the need for longer tempering times and multi-stage conditioning.

How to mill:

Australian wheats are generally free milling wheats with good flour yields and should not require any special techniques at the milling stage. The harder endosperm should make it easy to achieve starch damage targets where needed. As an indication of what to expect, see Appendix 1.

Australian wheats have a white seed coat. The lighter coloured bran should help reduce the visual impact of any bran specks that make it into the flour. This is particularly advantageous for products such as noodle and steamed buns.

Figure 4. *Red wheat (left) and white wheat (right)*

Part 2. Quantifying wheat value

Key point: High quality wheat, such as Australian wheat, may sometimes be more expensive but can represent better overall value when properly quantified. Quantifying wheat value by using accurate data to predict true costs of flour production can save significant money.

1. Define quality parameters and limits

Quality begins with the consumer. Food manufacturers will work out the best quality parameters for the product that their consumers eat. In most cases the flour customer, as well as the millers themselves, will already have a good idea of how quality is defined for a given product. For example, for a flour product, the customer may provide limits for specific parameters such as ash, moisture, protein, rheology and baking performance. These specifications have often been chosen based on years of experience using the particular flour product for specific food products. Where these quality specifications have not already been defined, trials may need to be conducted.

Product trials

Trials could involve food production comparing multiple flour types milled from multiple wheat types. Trial results need to be translated into flour and wheat specifications. Trials should not only determine which flour types work best but also why, i.e. which flour parameters have the most impact on the end-product. There may be many parameters that have some impact on quality. Deciding which wheat quality parameters are most important in determining end-product performance can be difficult. Defining the mathematical relationships between the parameters and the end-product performance can also be difficult. Linear regression and econometrics have been used to help with this, though it is beyond the scope of this information pack. However, once the critical parameters have been chosen and their relationships to quality defined, the suitability of various wheat lots, as well as their financial value, can then be assessed more easily.

Australian trials

For Australian varieties, much of this trial work has already been done by the Australian classification system. Most Australian suppliers have decades of experience supplying the right kind of wheat for each product. Some of the end products that can be made with the various Australian wheat grades have already been shown above. The Australian grading system ensures that only varieties with good milling qualities and the correct protein and starch qualities for good second-stage processing are included in a given grade. For example, premium udon noodles, for example, are often made from select ANW varieties which have high flour swelling properties from Western Australia. Other products can be made with a range of wheat grades. In cases where more specific information is required to match Australian wheat to an end product or process, AEGIC is well placed to provide advice with experience in commercial scale production and laboratory trials.

2. Quantify wheat value based on total flour production costs

There will often be a range of suppliers that a mill can choose from, each offering competing prices for their wheat. Mills need to properly quantify the true value of each lot if they are to make the best choices for their wheat blends.

When quantifying the value of each lot, the mill should start by standardising raw wheat prices to account for all costs involved in getting the wheat to the mill. This will involve adjusting the advertised price to a price that incorporates costs such as freight, insurance and vessel unloading.

The next step is to select wheat lots based on value. Sometimes wheat lots can be ruled out based on quality parameters. For example wheat with a low falling number may not be suitable for processing. However, there are often multiple lots that are not ruled out. Once a range of wheat batches have been found with adequate quality parameters, it may be tempting to select the cheapest batch based on the standardised raw wheat prices. However, quantifying wheat value requires a knowledge of how the value of a batch of wheat will change through the milling process. Since the milling process ends with flour, the total cost of producing flour from a given wheat lot is the best indicator of the true value because this takes into account the way that value may have been changed by the milling process. This includes changes due to factors such as screenings removed, moisture added during conditioning and the extraction rate of flour.

Another important factor is the value-return of selling co-products such as bran and screenings as wheat feed. Since wheatfeed can be sold, the revenue it generates can be seen as offsetting the cost of flour production. Therefore, the price of wheatfeed, and the amount of wheatfeed generated during the milling process, has an impact on the value of a wheat lot. The price of wheatfeed is usually the same regardless of wheat type.

In most cases the ancillary costs of things like power, packaging and labour will be similar regardless of which lot is milled, so we will not consider these in this information package.

Below is an example showing how to calculate the change in value through the milling process. Beginning with the price of raw wheat, we will work through the milling process to calculate the cost of producing 1 tonne (T) of clean wheat, then 1T of conditioned wheat, and finally 1T of flour. The wheat in this example is typical of what might be expected of a cheaper wheat lot, perhaps from a non-Australian exporter. The prices are in AUD.

Example 1. Cost of flour production

Step 1. Cost of 1T clean wheat

A batch of wheat is purchased for $325 per ton. This price takes into account all the costs up to the point of the wheat being stored at the mill. It contains 4% screenings, so when a tonne of raw wheat is cleaned only 0.960T will remain. We will assume that all of the material removed is saleable. The screenings can be sold as wheatfeed for $175 per ton, or $175 x 0.040T = $7 per tonne of raw wheat purchased. This reduces the effective raw wheat price to $325 – $7 = $318.

Since we only have **0.960T** of clean wheat, the cost of producing **1T** of clean wheat → **$318/0.960 = $331.25**

Step 2. Cost of 1T conditioned wheat

The raw moisture content of the wheat is 13%. Wheat at this moisture would not be saleable as milling wheat under the Australian regulations due to the storage risk. However, this is permissible under some non-Australian export regulations. The target moisture for conditioning is 15%. For this example, we will regard the price of water as negligible. The amount of water required to bring 1T of clean wheat to 15% moisture = (15 – 13) / (100 – 15) = 0.0235T of water. When this water is added to 1T of clean wheat the new weight = 1.0235T.

Since the cost of producing **1T** of clean wheat was **$331.25**, the cost of producing **1T** of conditioned wheat → **$331.25/1.0235 = $323.64**

Step 3. Cost of 1T flour

When milled, this conditioned wheat gives an extraction rate of 76.0% and produces 22.5% as co-products such as bran and pollard. 76.0% + 22.5% = 98.5%, therefore there is a milling loss of 1.5%, which is standard for many commercial mills, largely accounted for by moisture loss. The co-product can be sold as wheatfeed for 22.5% of $175 = $39.38 per tonne of conditioned wheat milled. This reduces the cost of producing flour by $323.64 – $39.38 = $284.26.

Since we have produced **0.760T** of flour from that conditioned wheat, the cost of producing **1T** of flour

↓

$284.26 / 0.760 = $374.03

↓

This number, the cost of flour production, is a better indication of the true financial value of the wheat than the raw wheat price.

The extraction rate used in the above calculations was based on the flour produced as a percentage of the wheat to first break. However, to simplify the calculations, the cost of flour production can be calculated using the raw wheat extraction rate. The raw wheat extraction rate, sometimes called the 'dirty wheat extraction rate', is the flour produced as a percentage of raw wheat received. Below is an example.

Example 2. Cost of flour production using raw wheat extraction rate

The same batch of wheat used in Example 1 is purchased for $325/T. The raw wheat extraction rate is 74.7%, and the proportion of wheatfeed generated is 24.6%. Again, these numbers do not tally to 100% due to milling loss. This wheatfeed would consist of screenings, bran, and the additional moisture added to the bran during conditioning, though we cannot tell the relative proportions of each. If the wheatfeed is sold for $175/T, the income from the wheatfeed would = $175 x 0.246 = $43.11.

Therefore, the cost of producing **0.747T** of flour

↓

$325 – $43.11
= $281.89

and the cost of producing **1T** of flour

↓

$281.89 / 0.747
= $377.48

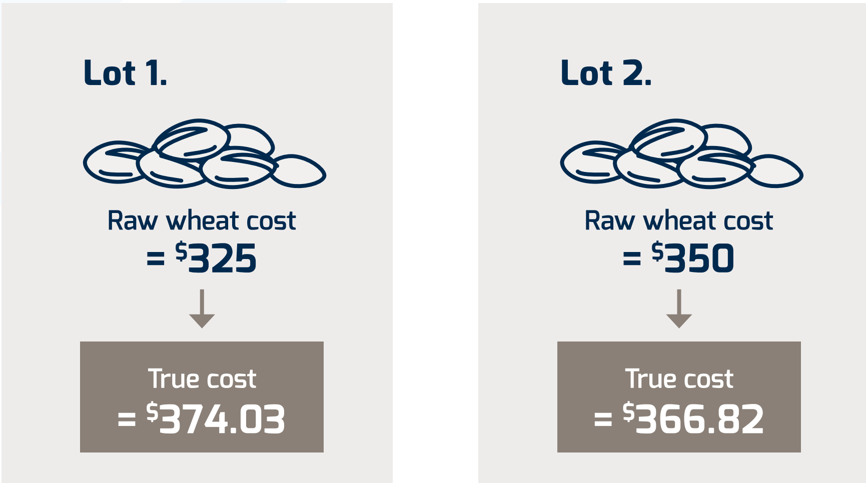
Whether we use the dirty wheat extraction or the longer method, the important figure when quantifying the value of wheat lots is not the raw wheat price but the cost of flour production. Both methods calculate this, but the longer method used in Example 1 gives more insight into why the costs of flour production are what they are. So, to make clear the impact of the wheat quality parameters in the proceeding calculations we will use the longer method.

Note that instead of using raw wheat extraction rate we could have used 'grist rate', which is simply the inverse – the amount of raw wheat milled to produce a tonne of flour. It is common for Australian milling wheat to achieve grist rates of 1.2, partly due to ash targets in the flours of around 0.6%, but also partly due to the low moisture and low screenings levels in Australian milling wheat.

We can use the cost of flour production to compare the batch of wheat used in the examples above (which we will call Lot 1) to another higher priced batch of wheat (which we will call Lot 2). Lot 2 (the higher priced batch) has been given quality parameters that are quite improved to highlight the effect of the differences. Some Australian wheats would have these qualities, though would not necessarily always be higher priced. Details are shown in Table 2 on the following page.

Table 2. Comparison of two wheat lots for value

	Lot 1	Lot 2	Value advantage of cheap batch
Raw wheat price ($/T)	$325	$350	$25
Screening (%)	4%	1.5%	
Cost to produce 1T clean wheat ($)	$331.25	$352.66	$21.41
Moisture (%)	13%	8%	
Cost to produce 1T conditioned wheat	$323.64	$325.83	$2.19
Extraction rate (%)	76%	80%	
Co-products yield (%)	22.5%	18.5%	
Cost to produce 1T flour ($)	**$374.03**	**$366.82**	**-$7.21**



The more expensive wheat is actually more valuable.

When only raw wheat prices are considered, the value advantage of Lot 1 seemed to be $25 over Lot 2. But once the production costs were calculated Lot 2 turned out to have a value advantage of $7.21 over Lot 1. In other words, the value advantage of Lot 1 is eroded during the milling process to the point that it represents less value to the mill than Lot 2. An informed wheat buyer would select Lot 2. Lot 2 also has additional practical advantages, such as the low screenings level potentially allowing a higher throughput through the screenroom, and the lower wheat moisture allowing longer safe storage times.

To get a clearer picture of the value advantage, we can repeat this exercise with the same two batches of wheat, but this time give them the same starting price. To make the comparison more realistic, we will also factor in the protein difference. Lot 1 yields a straight run flour with 10% protein rather than 11% protein. Therefore, the flour from Lot 1 requires gluten addition to achieve specification. Let's say that the available gluten product is 70% protein and $2100/T. Table 3 shows how the value changes through the milling process.

We see that producing a tonne of in-specification flour from Lot 1 is possible using gluten addition but is still $67.42 more expensive than Lot 2.

Table 3. Comparison of wheat batches for value using the same starting price

	Lot 1	Lot 2	Value advantage of cheap batch
Raw wheat price ($/T)	$350	$350	$0
Required SR flour protein (%)	11%	11%	
Actual SR flour protein (%)	10%	11%	
Wheatfeed price ($/T)	$175	$175	
Screenings (%)	4%	1.5%	
Cost of producing 1T clean wheat ($)	$357.29	$352.66	-$4.63
Wheat moisture (%)	13%	8%	
Cost of producing 1T conditioned wheat ($)	$349.08	$325.83	-$23.25
1st Bk extraction rate	76%	80%	
% wheatfeed produced	22.5%	18.5%	
Cost of producing 1T flour	$407.50	$366.82	-$40.68
Tonnes gluten required to achieve protein target	0.0160	0	
New flour weight (T)	1.0160	1.000	
Cost of producing 1T flour at target protein ($)	**$434.24**	**$366.82**	**-$67.42**

3. Use values from flour production costs for grist optimisation

Grist optimisation involves creating a grist which minimises costs while still ensuring a satisfactory flour quality. This is called a 'least cost grist'. For example, a general-purpose flour may be produced using mostly cheap wheat but with just enough high protein expensive wheat blended in to bring the protein level within specification. Gristing is sometimes carried out using pre-determined recipes that have been developed through experience. However, many mills have more sophisticated methods for creating optimal grists that work in their context.

Mathematical techniques do exist for determining optimal blends. Techniques such as linear programming have been around for decades and are well understood. [8, 9, 10, 11, 12, 13] A brief description of the methodology behind linear programming is given in Appendix 2.

Using the wheat batches from Table 2, with the original raw wheat prices of $325 for the cheaper batch and $350 for the expensive batch, we can use linear programming to determine the optimal blend of these wheats. For illustration purposes, we created a very simple optimisation model in Microsoft Excel using Solver (summary show in Table 4). The blend proportions are the output of this model. The model determines the cheapest blend of the available wheat batches that still achieves a final flour protein equal to or greater than 11%. So, in this example protein is the only quality parameter used (to keep things simple), but in practice other parameters or combination of parameters may be used. To use the most accurate quantification of wheat value, the model optimises for the cost of flour production (highlighted in blue), rather than the price of raw wheat. This also helps with calculating the impact of additives, since blending calculations that involve additives will need to convert wheat data to flour data and then solve for flour blends rather than wheat blends. A summary of the results from the model is shown in Table 4.

In Table 4 the model suggests we use 100% of Lot 2. This is the cheapest way to produce flour at or above 11% protein. This optimises the cost of flour production at $366.82 per tonne of flour produced.

But remember, these techniques or models are only as accurate as the data and assumptions used to create them. Simply assuming the cost of flour production, rather than actually calculating it using reliable milling data, can skew the outputs of these models.

Table 4. Summary of grist optimisation results using linear programming

	Lot 1	Lot 2	Gluten	Optimised blend
Raw wheat price ($/T)	325	350	2100	
SR flour protein (%)	10	11	70	11
Optimised blend proportions	0%	100%	0%	
Cost of producing 1T flour	374.03	366.82	2100.00	366.82

Of course, the outcome of these calculations is highly dependent on the fluctuating prices of both wheat and wheatfeed, so the above should be seen as one possible scenario only. However, we hope that this example can help teach millers about the principles of quantifying the value of wheat lots and the need to use up to date data in optimisation models.

AEGIC is conducting research to determine the true value of Australian milling grades using a commercial scale mill and will share this information in the future.

4. Other considerations

Production targets

The techniques described in this information package so far, techniques for quantifying the value of wheat lots and determining which lots to include in a grist, have assumed that production targets will be made available. For example, the calculations in Tables 4, 5 and 6 are based on a production target of 11% protein in the final flour. The LP model tries to find the optimal way to achieve that production target.

In practice, these production targets would be selected based on market demand. A selection of flour types with target specifications would need to be produced at target quantities to meet these demands, all the while minimising production costs.

Straight run flour verses other flour products

The production targets at a mill may in some cases be achieved by milling different grists in to straight run flours. Straight run flours include all the endosperm flour streams and only exclude the non-endosperm streams; the bran, pollard and germ streams.

The examples given in this information package so far have been limited to either straight run flours, or blends of straight run flours. In these examples, the cost of producing 1 tonne of each flour has been calculated. This calculation involved treating the selling price of wheatfeed as a way to offset the purchase prices of the wheat; first from the purchase price of the dirty wheat and then from the calculated 'purchase price' of the conditioned wheat. Since wheatfeed is the only by-product of straight run flour that can be sold, The price of wheatfeed is the only market-driven factor that is needed

But in many cases production of non-straight run flour products will also be required. It can be beneficial, and sometimes necessary, to exclude some of the endosperm-streams from a flour product. For example, if a low ash flour product is required, then the high ash endosperm streams will need to be excluded. If a market cannot be found for this high ash flour, it can in some cases be treated as wheateed. If a separate market can be found, we can think of this extra revenue as offsetting the production costs n a similar way that the wheatfeed did.

Cumulative curves can be used to show the proportions of the streams required to produce a flour product. They allow the miller to match a target flour specification to the highest flour yield that would stay below that specification. For example, a flour product may have an ash specification of 0.40% or below. The miller could plot a cumulative ash curve to determine what the maximum possible extraction rate would be at that ash level. An explanation of cumulative curves is given in Appendix 3.

Producing a high value product at its maximum extraction rate is often the optimal solution from a financial perspective. But sometimes producing a low ash product using the lowest ash streams is not optimal from a financial perspective. It may be less costly, in terms of production costs, to incorporate some high ash streams into the blend.

Flour stream selection, ie. determining the optimal selection of flour streams for inclusion into each flour product, is often a separate and subsequent task to grist selection. This is because flour stream selection is often performed after milling, because only after milling are the precise flour stream proportions and properties for each grist revealed.

The financially optimal selection of flour streams to include in each flour product can be calculated in multiple ways. Kalitsis et al [5] have shown how both linear programming and cumulative ash curves can be used to determine which flour streams to include in each flour blend, based on market factors. They provided a comparison of linear programming and cumulative ash curves and demonstrated how linear programming can give financially superior blending options.

Model specificity

Optimisation models are usually specific to a particular product and a particular mill. For example, a model might be designed for optimising the production of a particular type of sweet bun flour. That model will only be applicable to that type of sweet bun flour and cannot always be assumed to work for other sweet bun flours. The model will also be specific to a given mill due to the technical constraints at that mill. For example, the mill has a specific number of silos, blending capacity and dosing capabilities. Optimisation models will ideally account for specifics such as the limits in dosing accuracy present at the mill in question (Appendix 4). Sometimes physical constraints need to overrule the recommendations from theoretical models, such as when wheat lots must be chosen for reliability of supply rather than product quality considerations.

For these kinds of reasons any theoretical model needs to be seen as nothing more than a tool to assist millers who are already experienced with wheat buying and blending and are familiar with the physical facilities and limitations. Theoretical results should be seen as subordinate to the experience of those on the ground.

Practical considerations

Regardless of how reliable blending calculations and optimisation models are, the actual equipment used to perform the blending must also be appropriate and reliable if optimal outcomes are to be achieved.

The best data cannot compensate for poor technical facilities or physical processes. Silos must have laminar flow, weighers and dosers must be accurate. It is more difficult to get accurate dosing from volumetric scales. Also, the sampling techniques used to obtain data on wheat or flour batches need to be reliable.

Blending can be carried out to create least-cost-grists (but also to homogenise or create differentiated products). Blending can occur at several different points throughout the process from wheat receival to flour storage. The best point to blend can depend on the nature of the difference between the batches. Batches may significantly differ in:

- **No major way.** In this case the ideal point to blend is before cleaning.
- **Cleaning requirements**, such as wheat batches with different kernel sizes. In this case the ideal place to blend is at some point after cleaning. This allows the screenroom settings to be fine-tuned for each batch. However, the advantages of this need to be weighed up against the convenience of early blending.
- **Conditioning requirements**, such as batches with different moistures or tempering times. In this case the ideal point to blend is at some point after conditioning. This allows each batch to be conditioned to moistures and timeframes that are optimal for each batch.
- **Milling requirements**, such as batches with different grain hardness. Blending hard and soft wheat usually reduces mill efficiency. In this case it is better to blend the resulting flour. This allows the mill settings to be optimised for each batch.

Ideally, to maximise homogeneity, differing batches of wheat would be blended as early in the process as possible and then re-mixed as many times as possible after that. Ideally the wheat should be blended at least three or four times before milling[14]. For example, a wheat batch may be emptied into several bins, but drawn from two or three of these bins at the same time to increase homogeneity. In practice the decision will be heavily influenced by the facility available at the mill site and the costs of additional blending.

Many operations aim to blend enough grist wheat to last for three shifts[15]. This allows them to do all the blending in the day shift.

Conclusion

With wheat accounting for about 80% of flour production costs, careful wheat selection can have a major impact on a mill's financial position.

Choosing high quality Australian wheat can result in significant savings when compared to milling cheaper low-quality wheats, even if the Australian wheat is more expensive per tonne.

AEGIC hopes this information will be helpful to you in identifying opportunities for cost savings in your mill.

References

1. 'Module 3 5th Ed 2017 Mill Processes and Performance Flour Milling Training Distance Learning Programme nabim.pdf'.
2. 'Module 7 5th Ed 2016.pdf', *Google Docs*. https://drive.google.com/file/d/1sV7_FDr01chYV0IHSBc3hNDp6I-7ZRh7/view?usp=sharing&usp=embed_facebook (accessed Dec. 16, 2021).
3. Emily Dahl (Sept 2024) Wheat https://www.agriculture.gov.au/abares/research-topics/agricultural-outlook/wheat#daff-page-main (accessed Sept 18, 2024)
4. 'Grain Trade Australia, Section 02 – Wheat Trading Standards 202122 020821.pdf'. Accessed: Dec. 16, 2021. [Online]. Available: https://www.graintrade.org.au/sites/default/files/Standards/Section%2002%20-%20Wheat%20Trading%20Standards%20202122%20020821.pdf
5. J. Kalitsis, B. Minasny, K. Quail, and A. McBratney, 'Comparison of flour mill stream blending approaches: Linear programming verses ash curve' Cereal Chemistry, 2021;00:1–14
6. 'Go_Est_1 Supplied Products Agro Division.pdf'. Accessed: Dec. 16, 2021. [Online]. Available: http://russchinatrade.ru/assets/files/cn-ru-prod/Go_Est_1.pdf
7. 'BUHLER Milling Technology II 2010 Training Course Manual Wheat.pdf'.
8. T. Mutangi11, L. Nyanga, A. F. Van Der Merwe, T. C. Chikowore, and G. Kanyemba, 'A Linear Programming Model for Blending', 2013.
9. P. Steffan, 'An optimization model: minimizing flour millers' costs of production by blending wheat and additives', PhD Thesis, Kansas State University, 2012.
10. H. Avunduk, 'Linear programming model for optimum mixing the flour from sieve passages in flour mill industry', *New Trends and Issues Proceedings on Humanities and Social Sciences*, vol. 4, no. 10, pp. 361–368, 2017.
11. B. ELEVLI, H. ÖZTÜRK, and Z. KACIR, 'OPTIMIZATION of WHEAT AND FLOUR BLENDING FOR COST MINIMIZATION BY USING MATHEMATICAL MODELLING', *Kastamonu Üniversitesi Iktisadi ve Idari Bilimler Fakültesi Dergisi*, pp. 264–272, 2017.
12. M. Hayta and Ü. Çakmakli, 'OPTIMIZATION OF WHEAT BLENDING TO PRODUCE BREADMAKING FLOUR', J Food Process Engineering, vol. 24, no. 3, pp. 179–192, Aug. 2001, doi: 10.1111/j.1745-4530.2001.tb00539.x.
13. N. C. Haas, 'Optimizing wheat blends for customer value creation: A special case of solvent retention capacity', PhD Thesis, Kansas State University, 2011.
14. 'Blending for value'. https://www.world-grain.com/articles/10188-blending-for-value (accessed Dec. 06, 2021).
15. E. Posner and A. Hibbs, *Wheat Flour Milling*, 2nd ed. American Association of Cereal Chemists, Inc., 2005.

Appendix 1

AEGIC table of wheat specifications

			Test wt (kg/hl)	Grain weight (g)	Wheat moisture Brab	Particle size index (lab conco mill)	Flr Yld. 1996 Buhl mill	Wheat protein @11% m (%) Dumas	Flour protein @14% m (%) FE	Flour ash FE (14%)	Screenings whole grain (%)	Screenings broken grain (%)
			HWT	GrnWt	Moist	PSI	BuhMil	Dumas	Dumas		Sieve	
URegRef	LabNumber	ExternalID	HWT	GWT	BMSW	PSI	FY	WP	FP01	FA01	SV03	SV04
2023-927-1	12301530	APW 1 NSW	83.1	37.4	10.7	15	77.4	10.7	9.7	0.48	2.1	0.1
2023-927-1	12301531	ASW 1 NSW	84.1	37.0	10.7	17	77.8	9.5	8.4	0.47	1.5	0.1
2023-927-1	12301532	APW 1 Vic	83.6	45.3	11.1	17	79.4	10.7	9.7	0.48	1.3	0.2
2023-927-1	12301533	ASW 1 Vic	83.8	46.7	11.6	18	79.8	9.3	8.4	0.53	1.7	0.2

Appendix 2

A brief description of the methodology behind linear programming

The blending problem is translated into equations and/or inequalities. The mathematical formulation of the problem requires definition of decision variables, an objective function, and constraints. In the context of wheat blending, the decision variables represent the choice to be made about the quantities or proportions of each possible wheat that should be included in the grist. The objective function would be the final cost of the grist, which is a function of the decision variables; the amount of each type of wheat included in the grist, as well as their respective prices. The constraints are also functions of the decision variables but represent restrictions on the possibilities. In the context of wheat blending one constraint might be that the resulting grist must have a protein content within certain limits, or a baking volume above a certain limit, or that the amounts added must fit within what is possible based on the accuracy of the dosing scales present at the site.

These models can be designed in Microsoft Excel using Solver. As mentioned previously, deciding which parameters are the most critical as constraints can be the most difficult part of this. For example, when a wheat batch is received and tested, which quality parameters are most important for predicting noodle quality? Ideally only 4 or 5 quality parameters should be used and the relationship between the wheat quality parameter and a product quality parameter needs to be linear.

A similar approach can be used to create least-cost flour blends. The decision variables become flour streams or flour silos rather than wheat batches. However, creating a model that takes both wheat blending options and flour blending options into account at the same time is beyond the scope of this information package.

Appendix 3

Cumulative curves

Techniques such as plotting cumulative curves, such as ash curves for example, can assist millers in choosing which flour streams to include in the blended flour. Ash curves have the added benefit of indicating whether the mill is running at optimum efficiency in terms of maximising the amount of low ash flour produced from a known grist. If the shape of the curve changes, the efficiency has changed.

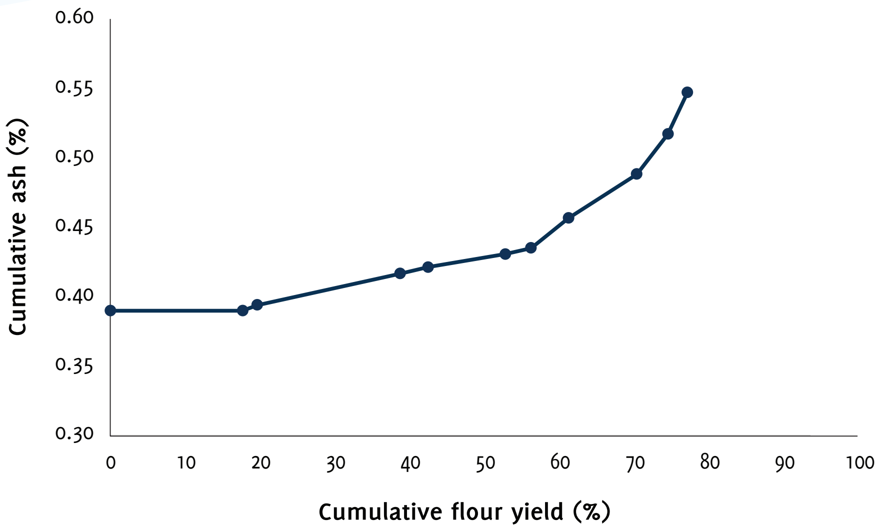
An ash curve is constructed by first getting data on every flour stream for ash level and also data on flow rate as a percentage of the flow rate to 1st break. The streams are then ranked from lowest to highest ash. Below is an example from the AEGIC Pilot Mill in Sydney, a small wheat mill used for research and training with a capacity of 500kg/h.

Flour streams	As % of wheat to 1st Bk	NIR ash
B	17.6	0.39
SZ	1.9	0.43
A	19.1	0.44
BM	3.8	0.47
C	10.3	0.47
1st + 2nd Bk	3.4	0.50
3rd + 4th Bk + DC	5.0	0.70
D	9.1	0.70
B2 + E	4.1	1.01
F + BF	2.6	1.40

Appendix 3 (continued)

The cumulative ash and flow percentage figures are then calculated and plotted on a graph. The graph below is an example:

Flour streams	Cumulative flour yield (%)	Cumulative ash
B	17.6	0.39
SZ	19.6	0.39
A	38.7	0.42
BM	42.5	0.42
C	52.8	0.43
1st + 2nd Bk	56.2	0.44
3rd + 4th Bk + DC	61.2	0.46
D	70.4	0.49
B2 + E	74.5	0.52
F + BF	77.1	0.55



This kind of technique can be used for other flour quality parameters as well including protein, moisture, colour, etc. Here we have used it for flour streams, but it could also be used for blending flour divides and blending flour from base flour bins.

The graph above shows the ash and flow percentage that would result if all the streams were blended starting with the lowest ash stream and moving through to the highest ash stream. This allows the miller to see the effect of excluding higher ash streams on the yield and ash of the remaining blend. However, it is not so good at determining the optimum streams to include. For example, it may be cheapest to mix some of the lowest and highest ash streams. These kinds of insights are more readily revealed through techniques such as linear programming, described above.

Appendix 4

The specific technical characteristics of equipment at a mill, such as the precision limits of dosing systems for flour or additives, play a crucial role in determining the most appropriate method for optimizing the grist blend. For instance, if the dosing scales operate with relatively low precision, attempting to model solutions at a finer level than the equipment can realistically handle would result in impractical or unfeasible solutions. Therefore, blending models must be designed to incorporate the precision constraints of the available dosing equipment. This can involve the use of **Integer Programming** or **Mixed-Integer Programming (MIP)**, which accounts for the discrete nature of the dosing increments, or the application of precision tolerance constraints. These techniques ensure that the model aligns with real-world operational limitations, although their detailed implementation go beyond the scope of this report.