



Optimization of wheat blends for end use application

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Optimization of Wheat Blends for End Use Application

1. Wheat Evaluation
 - Physical aspects
2. Quality Evaluation
 - Functional properties
 - Linear properties
3. Linear programming concepts and application
 - Wheat/Flour blends formulation using linear programming
4. Multi blend optimization concepts
 - Evaluate various scenarios where production of multiple blends need to be optimized that may use a specific wheat in limited supply



Optimization of Wheat Blends for End Use Application

1. Wheat Evaluation

- Physical aspects



Selection of wheat

Wheat Type	Wheat A	Wheat B
Wheat Cost per tonne, \$	330.60	330.60
Foreign Material, %	0.75	0.4



Selection of wheat

Wheat Type	Wheat A	Wheat B
Wheat Cost per tonne, \$	330.60	330.60
Foreign Material, %	0.75	0.4
Natural Moisture, %	12.9	13.1



Selection of wheat

Wheat Type	Wheat A	Wheat B
Wheat Cost per tonne, \$	330.60	330.60
Foreign Material, %	0.75	0.4
Natural Moisture, %	12.9	13.1
Flour Extraction, %	74.8	74.6



Selection of wheat

Wheat Type	Wheat A	Wheat B
Wheat Cost per tonne, \$	330.60	330.60
Foreign Material, %	0.75	0.4
Natural Moisture, %	12.9	13.1
Flour Extraction, %	74.8	74.6
Ash in Flour, %	0.5	0.49



Selection of wheat

Wheat Type	Wheat A	Wheat B
Wheat Cost per tonne, \$	330.60	330.60
Foreign Material, %	0.75	0.4
Natural Moisture, %	12.9	13.1
Flour Extraction, %	74.8	74.6
Ash in Flour, %	0.5	0.49
Wheat Protein, %	13.2	13.0
Falling number, sec	300	325



Selection of wheat

Wheat Type	Wheat A	Wheat B	Wheat C	Wheat D	Wheat E
Wheat Cost per tonne, \$	330.60	330.60	325.50	315.80	305.25
Foreign Material, %	0.75	0.4	1.0	1.5	1.75
Natural Moisture, %	12.9	13.1	13.2	13.3	12.3
Flour Extraction, %	74.8	74.6	74.2	74.3	74.1
Ash in Flour, %	0.5	0.49	0.51	0.52	0.53
Wheat Protein, %	13.2	13.0	12.9	11.5	11.2
Falling number, sec	300	325	310	270	260



COST OF FLOUR DUE TO WHEAT COST



COST OF A BAG OF
FLOUR IS ~80 % DUE
TO THE COST OF WHEAT



OPTIMIZATION OF WHEAT BLEND

WHEAT EVALUATION

QUALITY DATA EVALUATION

USE OF LINEAR PROGRAMMING TO WORK
OUT ECONOMIC SOLUTIONS



WHEAT EVALUATION

1. NATURAL MOISTURE CONTENT
2. FOREIGN MATERIAL
3. FLOUR EXTRACTION
4. FLOUR ASH CONTENT
5. OPTIMUM MILLING MOISTURE
6. MILLFEED PRICES

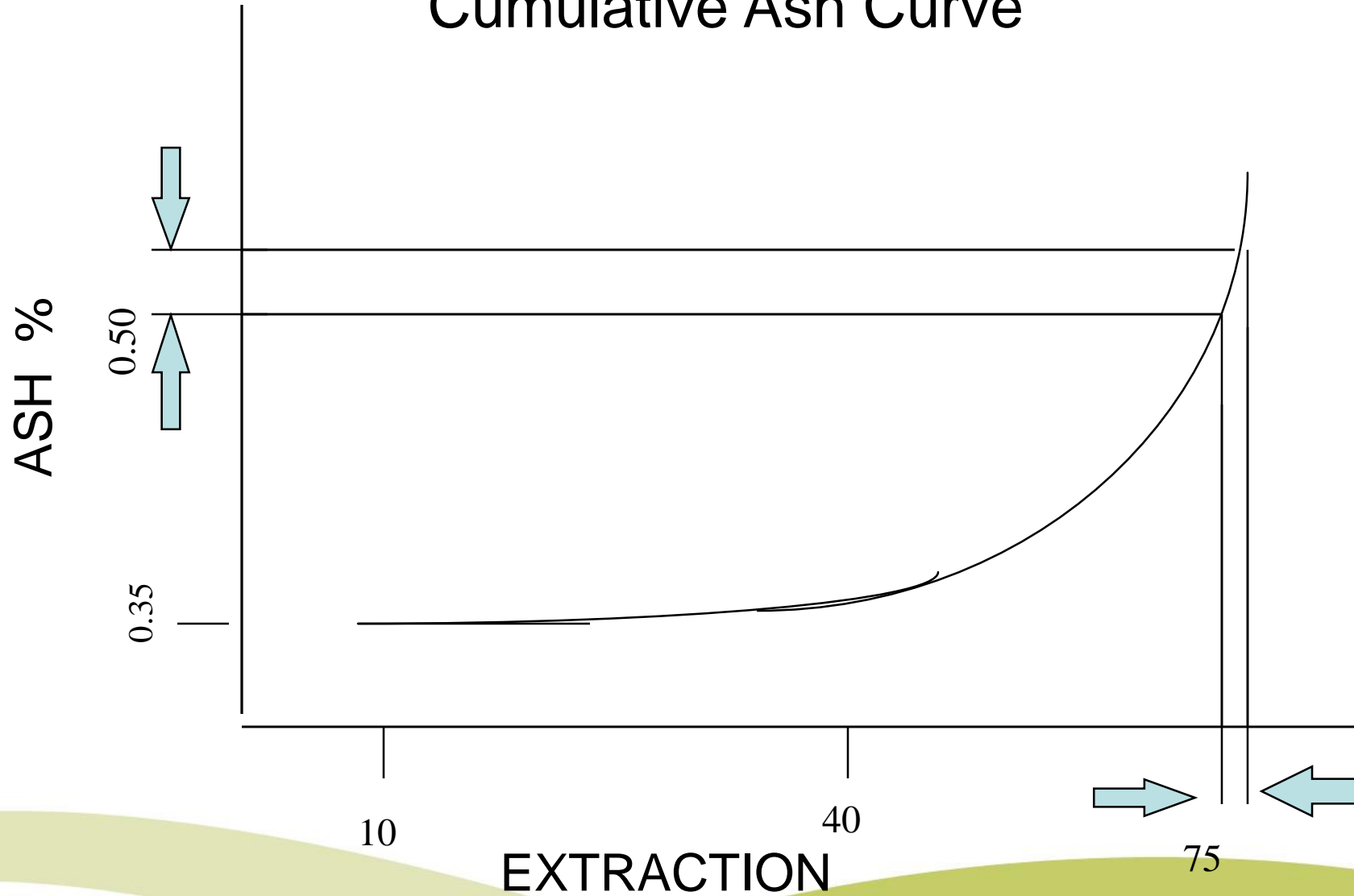


ASH CORRECTION

$\pm 0.01\%$ ASH = 0.4% EXT. $\bar{+}$

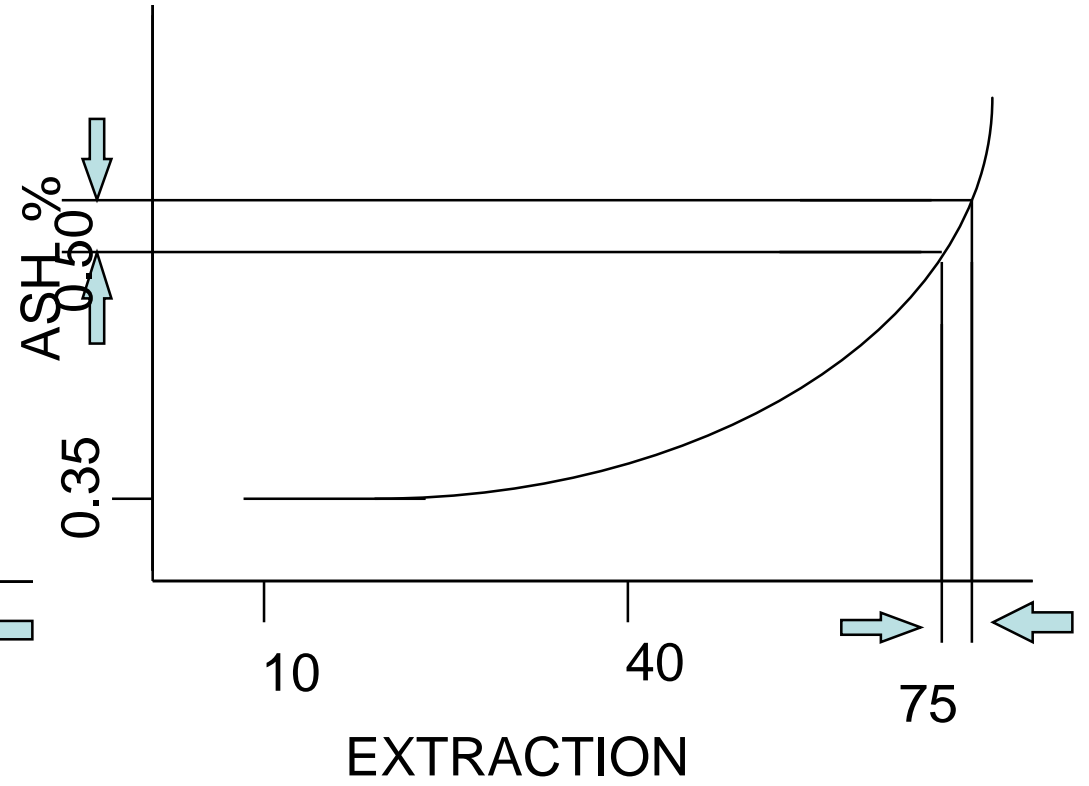
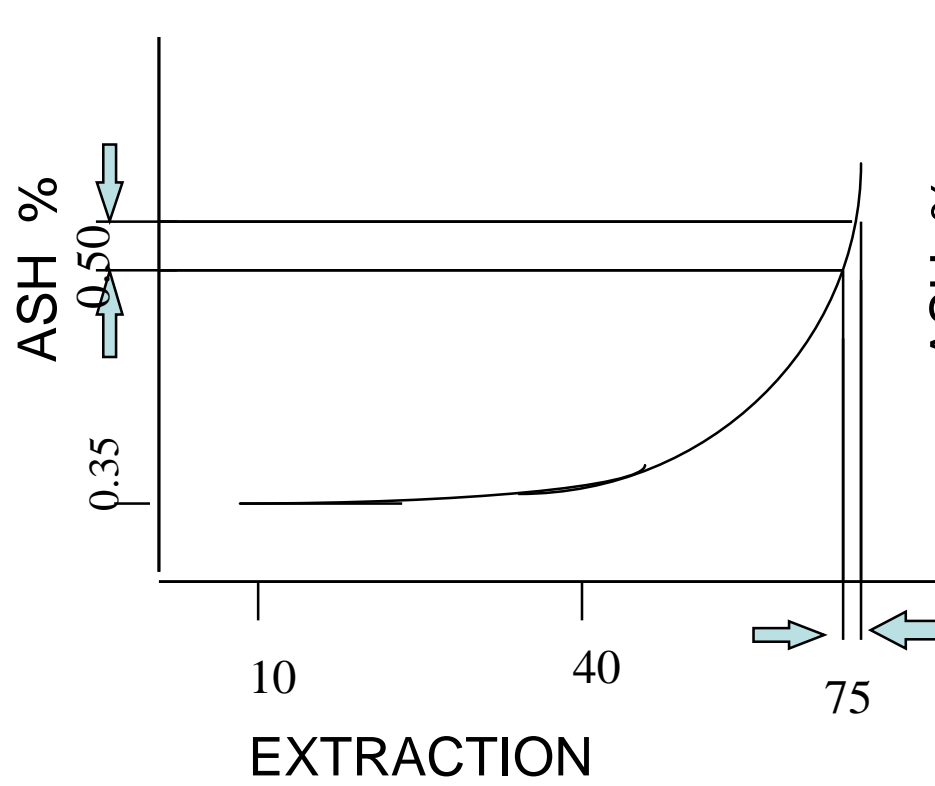


Cumulative Ash Curve





Cumulative Ash Curves





MOISTURE ADDITION

$$\text{WATER} = \text{WHEAT} \times \frac{(M2 - M1)}{(100 - M2)}$$



Calculation of Cost of Flour

Wheat Type	Wheat A
Wheat Cost per tonne, \$	330.60
Foreign Material, %	0.75
Natural Moisture, %	12.9
Milling Moisture, %	16.0
Flour Extraction, %	74.8
Ash in Flour, %	0.5
Std. Ash Required, %	0.48
Ash Correction, %	0.4
Ash Corr. Extr., %	74.0



Calculation of Cost of Flour

Raw Wheat, kg.	1000
Less Foreign Mat., kg.	7.5
Clean Untemp. Wheat, kg.	992.5
Water to be Added, kg.	36.63
Clean Temp. Wheat, kg.	1029.13
Flour Produced, kg.	761.55
Low Grade Flour %	0.00
Low Grade flour produced, kg	0.00
Milling Loss, %	1.75
Qty. of Milling Loss, kg.	18.01
Net Millfeed, kg.	249.56
Plus Foreign Mat., kg.	7.5
Gross Millfeed, kg.	257.06



Calculation of Cost of Flour

Market Val of Millfd / Tonne, \$	100
Value of Millfeed , \$	25.71
Market Val of Low Grade Flour / Tonne, \$	175.00
Value of Low Grade Flour, \$	0.00
Cost of Flour/ tonne of wheat gr., \$	304.89
Cost of Flour/tonne, \$	400.36



Wheat Evaluation Exercise

Wheat Type	Wheat A	Wheat B	Wheat C	Wheat D	Wheat E
Wheat Cost per tonne, \$	330.60	330.60	325.50	315.80	305.25
Foreign Material, %	0.75	0.4	1	1.5	1.75
Natural Moisture, %	12.9	13.1	13.2	13.3	12.3
Milling Moisture, %	16.0	16.0	16.0	15.5	15.5
Flour Extraction, %	74.8	74.6	74.2	74.3	74.1
Ash in Flour, %	0.5	0.49	0.51	0.52	0.53
Std. Ash Required, %	0.48	0.48	0.48	0.48	0.48
Ash Correction, %	0.4	0.4	0.4	0.4	0.4
Ash Corr. Extr., %	74.0	74.2	73.0	72.7	72.1
Raw Wheat, kg.	1000	1000	1000	1000	1000
Less Foreign Mat., kg.	7.5	4	10	15	17.5
Clean Untemp. Wheat, kg.	992.5	996	990	985	982.5
Water to be Added, kg.	36.63	34.39	33.00	25.64	37.21
Clean Temp. Wheat, kg.	1029.13	1030.39	1023.00	1010.64	1019.71
Flour Produced, kg.	761.55	764.55	746.79	734.74	735.21
Low Grade Flour %	0.00	0.00	0.00	0.00	0.00
Low Grade flour produced, kg	0.00	0.00	0.00	0.00	0.00
Milling Loss, %	1.75	1.75	1.75	1.75	1.75
Qty. of Milling Loss, kg.	18.01	18.03	17.90	17.69	17.84
Net Millfeed, kg.	249.56	247.81	258.31	258.22	266.65
Plus Foreign Mat., kg.	7.5	4	10	15	17.5
Gross Millfeed, kg.	257.06	251.81	268.31	273.22	284.15
Market Val of Millfd / Tonne, \$	100	100	100	100	100
Value of Millfeed, \$	25.71	25.18	26.83	27.32	28.42



Wheat Evaluation Exercise

Market Val of Low Grade Flour / Tonne, \$	175.00	175.00	175.00	175.00	175.00
Value of Low Grade Flour, \$	0.00	0.00	0.00	0.00	0.00
Cost of Flour/					
tonne of wheat gr., \$	304.89	305.42	298.67	288.48	276.83
Cost of Flour/tonne, \$	400.36	399.48	399.94	392.63	376.54



Wheat Evaluation Exercise

Market Val of Low Grade Flour / Tonne, \$	175.00	175.00	175.00	175.00	175.00
Value of Low Grade Flour, \$	0.00	0.00	0.00	0.00	0.00
Cost of Flour/					
tonne of wheat gr., \$	304.89	305.42	298.67	288.48	276.83
Cost of Flour/tonne, \$	400.36	399.48	399.94	392.63	376.54

Using What-If Analysis Goal Seek Feature

Goal Seek	?	X
Set cell:		C33
To Value:		400.36
By Changing Cell		\$C\$4



Wheat Evaluation Exercise

Market Val of Low Grade Flour / Tonne, \$	175.00	175.00	175.00	175.00	175.00
Value of Low Grade Flour, \$	0.00	0.00	0.00	0.00	0.00
Cost of Flour/					
tonne of wheat gr., \$	304.89	305.42	298.67	288.48	276.83
Cost of Flour/tonne, \$	400.36	399.48	399.94	392.63	376.54

Using What-If Analysis Goal Seek Feature

Goal Seek	?	
Set cell:	C33	331.27
To Value:	400.36	400.36
By Changing Cell	\$C\$4	400.36



Wheat Evaluation Exercise

Market Val of Low Grade Flour / Tonne, \$	175.00	175.00	175.00	175.00	175.00
Value of Low Grade Flour, \$	0.00	0.00	0.00	0.00	0.00
Cost of Flour/ tonne of wheat gr., \$	304.89	305.42	298.67	288.48	276.83
Cost of Flour/tonne, \$	400.36	399.48	399.94	392.63	376.54
Wheat required for 1 tonne of flour, t	1.313	1.308	1.339	1.361	1.360
Cost of wheat, \$	434.11	432.41	435.87	429.81	415.19
Cost of wheat after millfeed credit, \$	408.41	407.23	409.03	402.49	386.77



QUALITY DATA EVALUATION

EVALUATION OF DATA AFFECTING FUNCTIONAL PROPERTIES

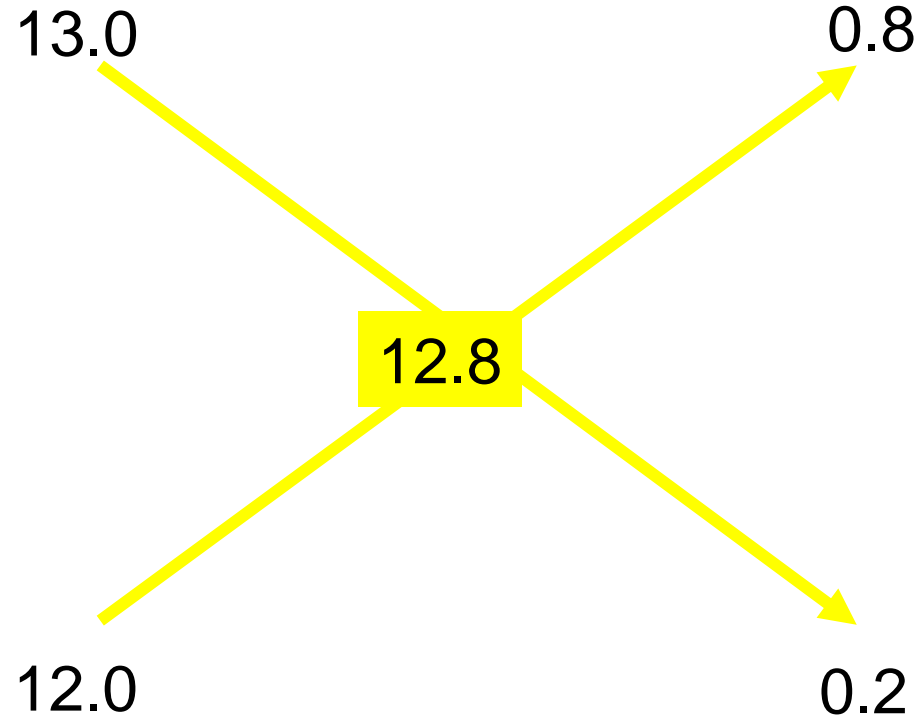
WHILE ALL TYPES OF QUALITY DATA SHOULD BE KEPT IN MIND, BUT ONLY THE DATA THAT ARE LINEAR SHOULD BE USED IN THE PROGRAM, SUCH AS ASH, PROTEIN AND LIQUEFACTION NUMBER



BLENDING FOR PROTEIN

WHEAT A 13.0

$$0.8 \times 100 / (0.8 + 0.2) = 80\%$$



WHEAT B 12.0

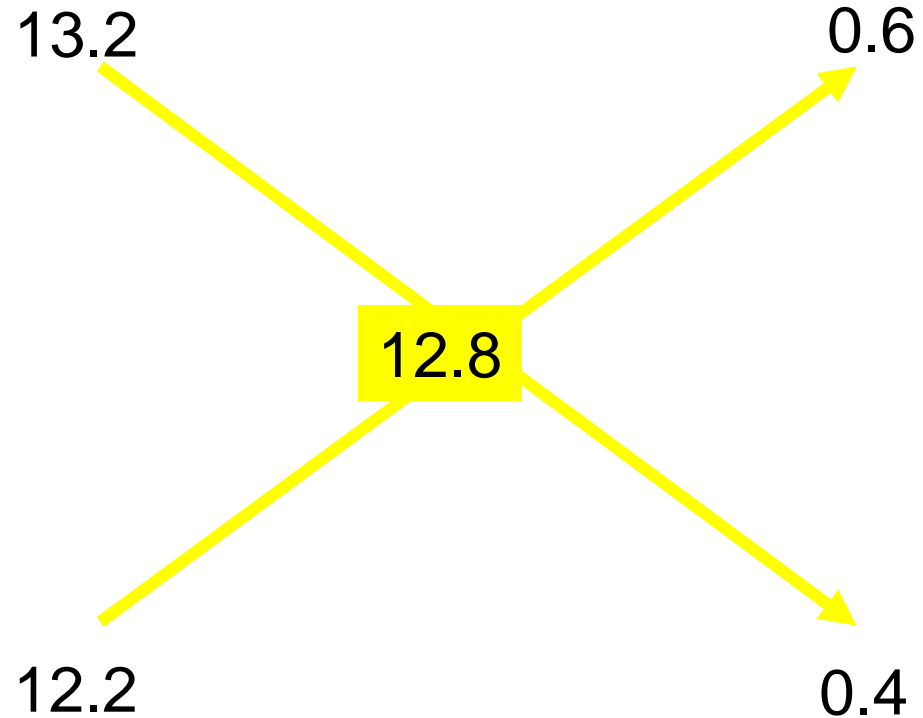
$$0.2 \times 100 / (0.8 + 0.2) = 20\%$$



BLENDING FOR PROTEIN

WHEAT A 13.0

$$0.6 \times 100 / (0.6 + 0.4) = 60\%$$



WHEAT B 12.0

$$0.4 \times 100 / (0.6 + 0.4) = 40\%$$



LINEAR QUALITY DATA

LINEAR NUMBERS ARE THOSE THAT FOLLOW MATHEMATICAL RULES
FOR EXAMPLE, FALLING NO. IS NOT LINEAR BUT LIQUEFACTION
NUMBER IS WHICH IS AS FOLLOWS:

$$\text{L.N.} = \frac{6000}{\text{F.N.} - 50}$$



LINEAR QUALITY DATA

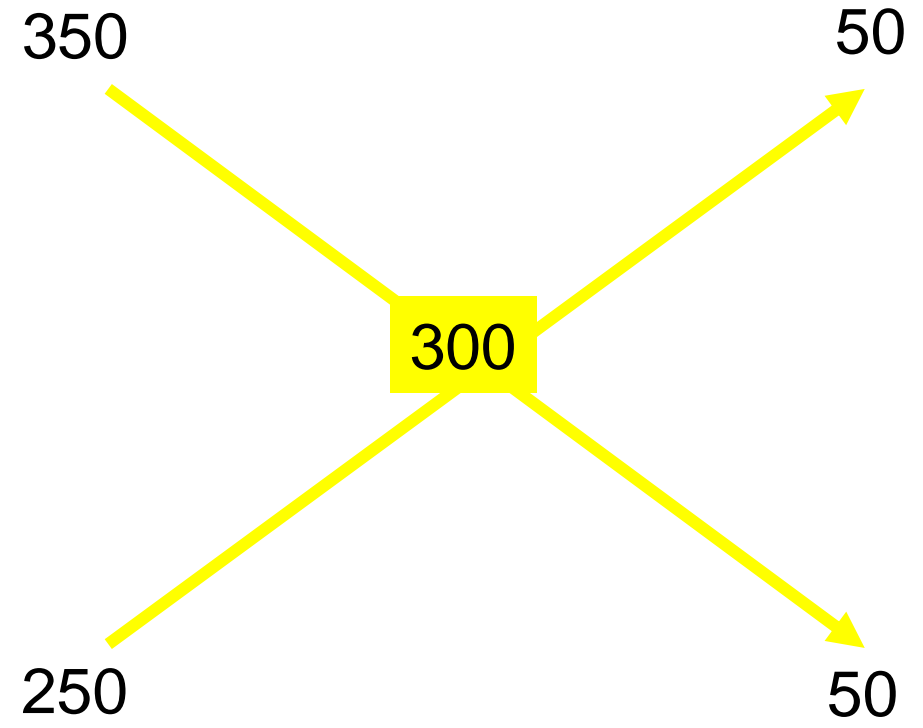
F.N.	250	300	450
	↓	↓	↓
L.N.	30	24	15



BLENDING FOR FALLING NO.

WHEAT A 13.0

$$50 \times 100 / (50 + 50) = 50\%$$



WHEAT B 12.0

$$50 \times 100 / (50 + 50) = 50\%$$



BLENDING FOR LIQUEFACTION NO.

WHEAT A 13.0

$$6 \times 100 / (6 + 4) = 60\%$$

20

6

24

30

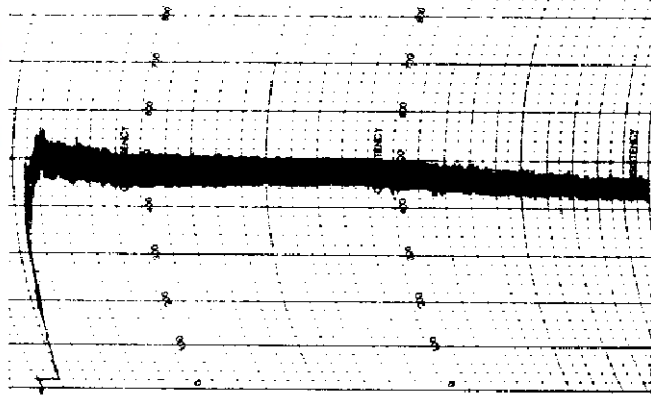
4

WHEAT B 12.0

$$4 \times 100 / (6 + 4) = 40\%$$

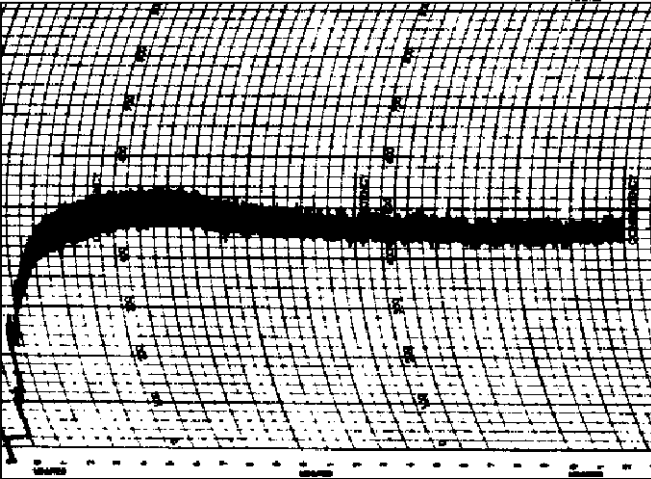


Linear Properties & Farinograph Stability



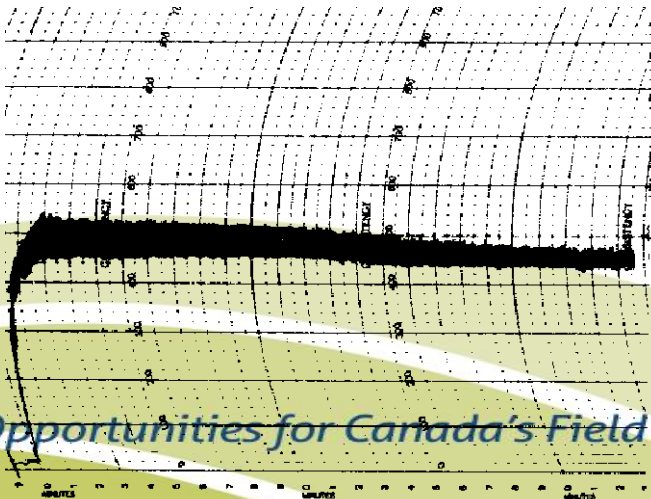
Flour 1

Stability 8.5



Flour 2

Stability 9.0



Blend

Flour 1 70%

Stability 13.9

Flour 2 30%

Source: Kansas wheat commission Brabender HRW Study

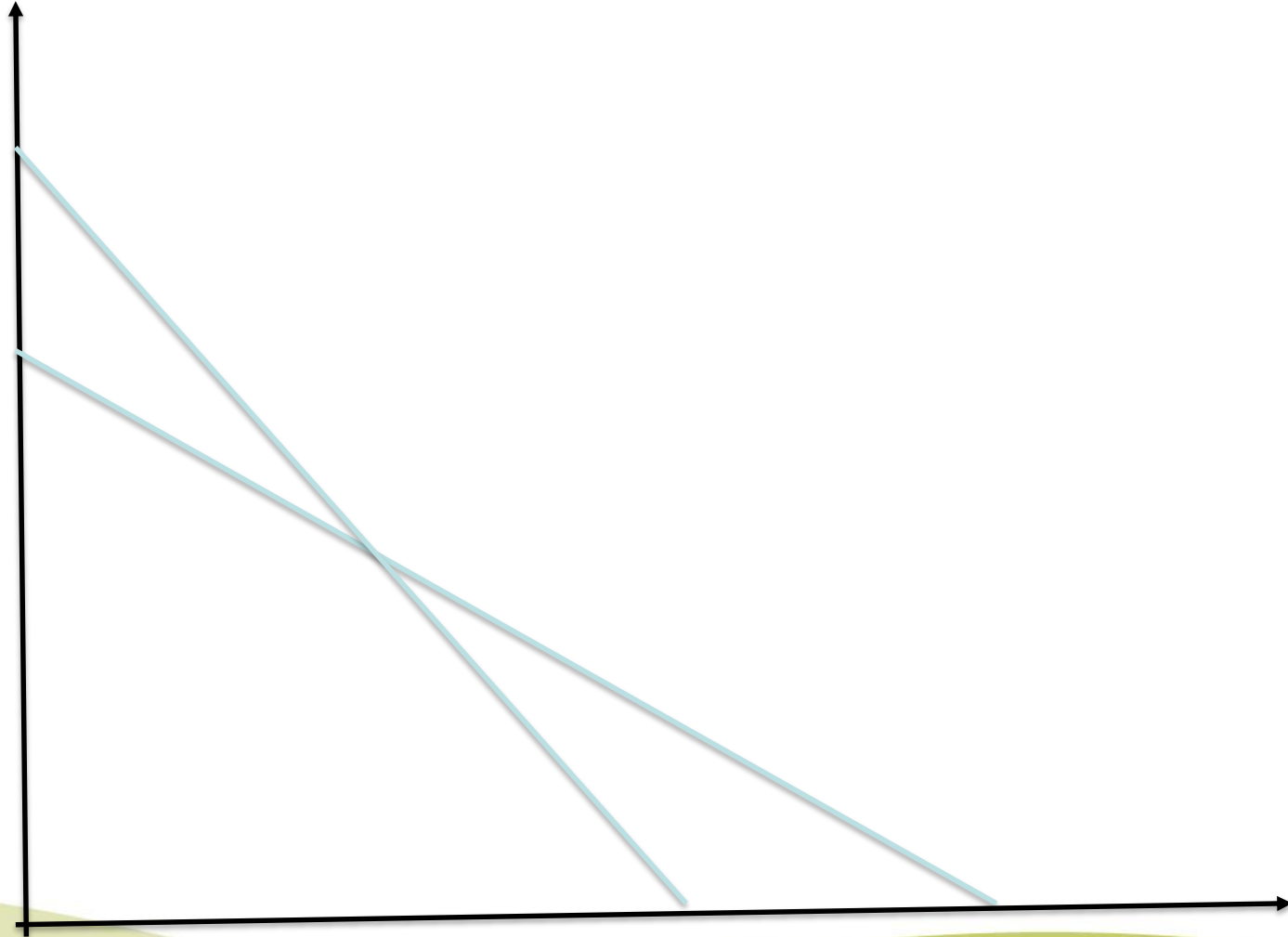
www.cigi.ca



USE OF LINEAR PROGRAMMING TO WORK OUT ECONOMIC SOLUTIONS



LINEAR PROGRAMMING CONCEPTS



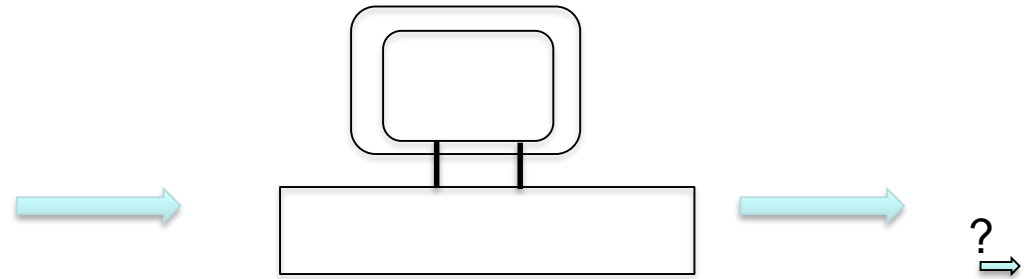


USE OF LINEAR PROGRAMMING TO WORK OUT ECONOMIC SOLUTIONS





USE OF LINEAR PROGRAMMING TO WORK OUT ECONOMIC SOLUTIONS



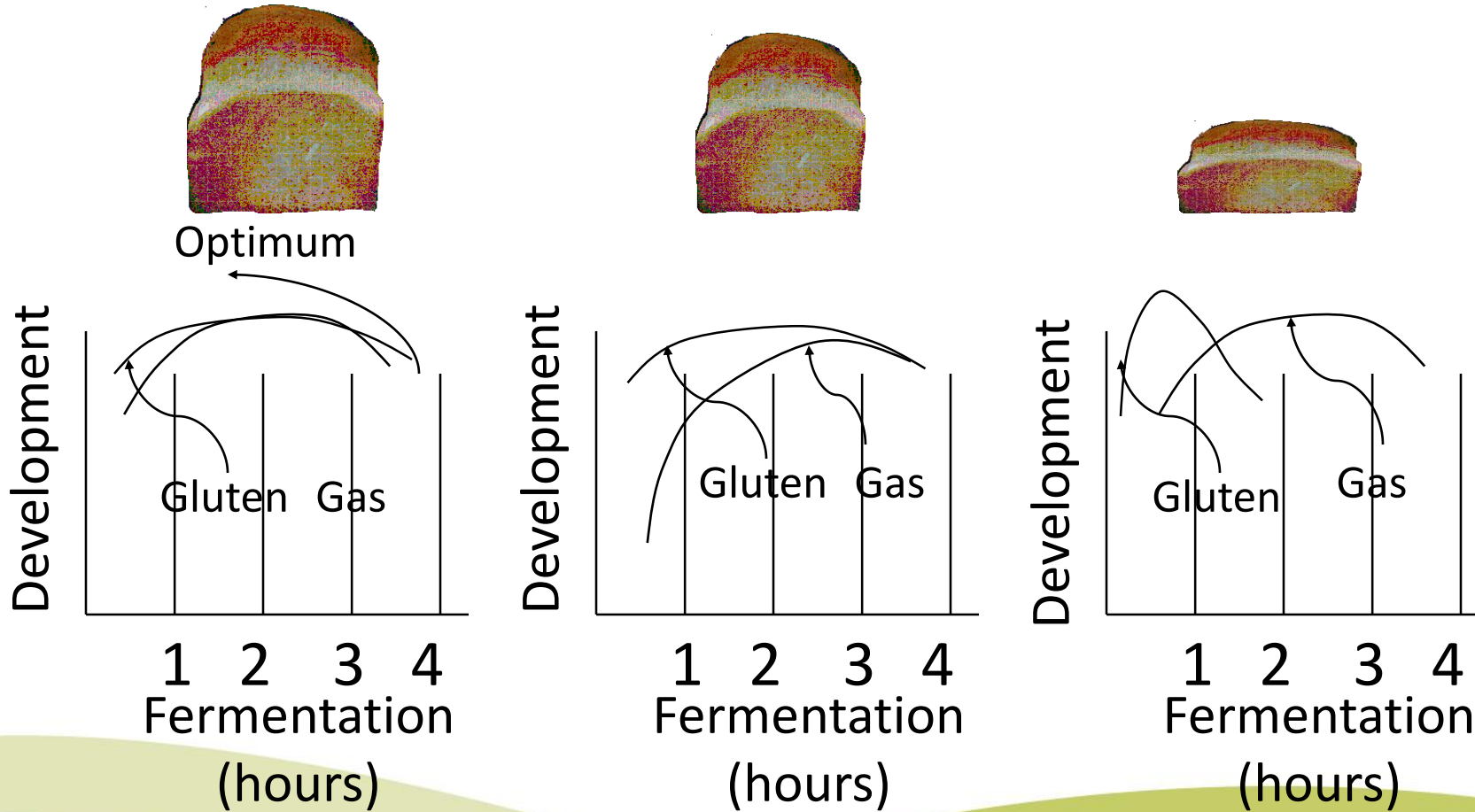


Bread Quality

- Gas Production
- Gas Retention



Balance between gas production and gas retention





LARGE BAKERS BLEND

TARGETED SPECIFICATIONS

	Min.	Max.
Protein	0.128	0.132
L.N.	0.00	0.24
W	3.20	3.40
Total Prod	1.00	



LARGE BAKERS BLEND

WHEAT QUALITY DATA & COSTS

	Wheat A	Wheat B	Wheat C	Wheat D
Wheat 1t, \$	300.00	400.00	450.00	410.00
Protein, %	0.12	0.13	0.15	0.13
L.N.	0.25	0.20	0.26	0.25
W	2.80	3.20	3.50	3.30



LARGE BAKERS BLEND

WHEAT QUALITY DATA & COSTS

	Wheat A	Wheat B	Wheat C	Wheat D
Wheat 1t, \$	300.00	400.00	450.00	410.00
Protein, %	0.12	0.13	0.15	0.13
L.N.	0.25	0.20	0.26	0.25
W	2.80	3.20	3.50	3.30
Portion /tonne	0.26	0.26	0.28	0.20
Cost of wheat, \$	78.26	102.42	126.09	83.19



Solver Parameters

Solver Parameters

Set Objective:

To: Max Min Value Of:

By Changing Variable Cells:

Subject to the Constraints:

- \$I\$8 >= 0
- \$I\$8 >= 0
- \$F\$13 <= \$H\$20**
- \$F\$15 <= \$H\$22
- \$F\$14 >= \$G\$21
- \$G\$8 >= 0
- \$F\$15 >= \$G\$22
- \$F\$16 = \$G\$23
- \$F\$14 <= \$H\$21
- \$C\$8 >= 0
- \$F\$13 >= \$G\$20

Make Unconstrained Variables Non-Negative

Select a Solving Method:

Solving Method
Select the GRG Nonlinear engine for Solver Problems that are smooth nonlinear. Select the LP Simplex engine for linear Solver Problems, and select the Evolutionary engine for Solver problems that are non-smooth.



Buttons: Add, Change, Delete, Reset All, Load/Save, Options

Buttons: Help, Solve, Close



Incorporating Constraints

Change Constraint ✕

Cell Reference:  Constraint: 



Solution Options

✕

Solver Results

Solver found a solution. All Constraints and optimality conditions are satisfied.

KeeP Solver Solution

Restore Original Values

Return to Solver Parameters Dialog

Reports

Answer
Sensitivity
Limits

Outline Reports

Solver found a solution. All Constraints and optimality conditions are satisfied.

When the GRG engine is used, Solver has found at least a local optimal solution. When Simplex LP is used, this means Solver has found a global optimal solution.



Solution Options

Solver Results ✕

Solver could not find a feasible solution.

Keep Solver Solution

Restore Original Values

Return to Solver Parameters Dialog

Outline Reports

Reports

Feasibility

Feasibility-Bounds

Save Scenario...

Solver could not find a feasible solution.

! Solver can not find a point for which all Constraints are satisfied.



LARGE BAKERS BLEND

TARGETED SPECIFICATIONS & WHEAT SELECTED PER TONNE BASIS

				Min.	Max.	Blend
Wheat A	0.26		Protein	0.128	0.132	13.20
Wheat B	0.26		L.N.	0.00	0.24	24.00
Wheat C	0.28		W	3.20	3.40	320.00
Wheat D	0.20		Total Prod	1.00		100.00

Opt. Cost \$389.95



SPREADSHEET LARGE BAKERS BLEND

	Wheat A	Wheat B	Wheat C	Wheat D		
Wheat 1t, \$	300.00	400.00	450.00	410.00		
Protein, %	0.12	0.13	0.15	0.13		
L.N.	0.25	0.20	0.26	0.25		
W	2.80	3.20	3.50	3.30		
Portion /tonne	0.26	0.26	0.28	0.20		
Cost of wheat, \$	78.26	102.42	126.09	83.19		
		Protein	0.13			
		L.N.	0.24			
		W	3.20			
		Total Prod	1.00			
			Min.	Max.	Blend	
	Wheat A	0.26	Protein	0.128	0.132	13.20
	Wheat B	0.26	L.N.	0.00	0.24	24.00
	Wheat C	0.28	W	3.20	3.40	320.00
	Wheat D	0.20	Total Prod	1.00		100.00
		Opt. Total Revenue	389.95			



STRONG BAKERS BLEND

TARGETED SPECIFICATIONS

	Min.	Max.
Protein	0.136	0.14
L.N.	0.00	0.26
W	3.00	3.40
Total Prod	1.00	



STRONG BAKERS BLEND

WHEAT QUALITY DAT & COSTS

	Wheat A	Wheat B	Wheat C	Wheat D
Wheat 1t, \$	300.00	400.00	450.00	410.00
Protein, %	0.12	0.13	0.15	0.13
L.N.	0.25	0.20	0.26	0.25
W	2.80	3.20	3.50	3.30
Portion /tonne	0.36	0.00	0.64	0.00
Cost of wheat, \$	108.00	0.00	288.00	0.00



STRONG BAKERS BLEND

TARGETED SPECIFICATIONS & WHEAT SELECTED PER TONNE BASIS

			Min.	Max.	Blend
Wheat A	0.36	Protein	0.136	0.14	13.60
Wheat B	0.00	L.N.	0.00	0.26	25.64
Wheat C	0.64	W	3.00	3.40	324.80
Wheat D	0.00	Total Prod	1.00		100.00
	Opt. Cost		\$396.00		



FANCY CLEARS BLEND

TARGETED SPECIFICATIONS

	Min.	Max.
Protein	0.14	14.8
L.N.	0.00	0.28
W	3.00	3.50
Total Prod	1.00	



FANCY CLEARS BLEND

WHEAT QUALITY DAT & COSTS

	Wheat A	Wheat B	Wheat C	Wheat D
Wheat 1t, \$	300.00	400.00	450.00	410.00
Protein, %	0.12	0.13	0.15	0.13
L.N.	0.25	0.20	0.26	0.25
W	2.80	3.20	3.50	3.30
Portion /tonne	0.20	0.00	0.80	0.00
Cost of wheat, \$	60.00	0.00	360.00	0.00



FANCY CLEARS BLEND

TARGETED SPECIFICATIONS & WHEAT SELECTED PER TONNE BASIS

			Min.	Max.	Blend
Wheat A	0.20	Protein	0.14	14.8	14.00
Wheat B	0.00	L.N.	0.00	0.28	25.80
Wheat C	0.80	W	3.00	3.50	336.00
Wheat D	0.00	Total Prod	1.00		100.00
	Opt. Cost	420.00			



WHOLE WHEAT FLOUR BLEND

TARGETED SPECIFICATIONS

	Min.	Max.
Protein	0.14	14.8
L.N.	0.00	0.24
W	3.20	3.50
Total Prod	1.00	



WHOLE WHEAT FLOUR BLEND

WHEAT QUALITY DAT & COSTS

	Wheat A	Wheat B	Wheat C	Wheat D
Wheat 1t, \$	300.00	400.00	450.00	410.00
Protein, %	0.12	0.13	0.15	0.13
L.N.	0.25	0.20	0.26	0.25
W	2.80	3.20	3.50	3.30
Portion /tonne	0.00	0.33	0.67	0.00
Cost of wheat, \$	0.00	133.33	300.00	0.00



PRODUCTION PLANNING & WHEAT DATA

W	<u>FLOUR MARGINS</u>			<u>Flour INVENTORY</u>			<u>WHEAT INVENTORY & QUALITY</u>			
	Cost	Selling price	Margin	Order	Available	Production	Wheat A	Wheat B	Wheat C	Wheat D
Family Flour										
Large Bakers Flour	389.95	410.00	20.05	300	50	250	0.26	0.26	0.28	0.20
Small Bakers Flour	396.00	415.00	19.00	300	50	250	0.36	0.00	0.64	0.00
Fancy Clears Flour	420.00	450.00	30.00	200	0	200	0.20	0.00	0.80	0.00
Whole wheat Flour	433.33	460.00	26.67	200	10	190	0.00	0.33	0.67	0.00
Wheat required							195	64	390	51
Wheat available							250	400	350	350
Wheat 1t, \$							300.00	400.00	450.00	410.00
Protein, %							0.12	0.13	0.15	0.13
L.N.							0.25	0.20	0.26	0.25
W							2.80	3.20	3.50	3.30



OPTIMIZATION OF MULTIPLE BLENDS

	Blend 1	Blend 2	Blend 3	Blend 4	
Cost of blend per tonne, \$	389.95	396	420	433.33	
Wheat C, %	0.28	0.64	0.80	0.67	
Margins, \$	20.05	19.00	30.00	26.67	
Wheat C, tonnes	Opt Rev.				
Production, tonnes					
			Min	Max	Select
	Wheat C		100	500	
	Blend 1		0	0	
	Blend 2		0	100	
	Blend 3		200	400	
	Blend 4		0	600	
	Production		800	900	



OPTIMIZATION OF MULTIPLE BLENDS

INFEASIBLE SOLUTION

	Blend 1	Blend 2	Blend 3	Blend 4	
Cost of blend per tonne, \$	389.95	396	420	433.33	
Wheat C, %	0.28	0.64	0.80	0.67	
Margins, \$	20.05	19.00	30.00	26.67	
Quantity, tonnes	0	100	200	414	
Revenue, \$	0.00	1900.00	6000.00	11040.00	
Wheat C, tonnes	500	Opt Rev.		18940.00	
Production, tonnes	714	Infeasible			
			Min	Max	Select
	Wheat C		100	500	500
	Blend 1		0	0	0
	Blend 2		0	100	100
	Blend 3		200	400	200
	Blend 4		0	600	414
	Production		800	900	714



OPTIMIZATION OF MULTIPLE BLENDS

FEASIBLE SOLUTION

	Blend 1	Blend 2	Blend 3	Blend 4	
Cost of blend per tonne, \$	389.95	396	420	433.33	
Wheat C, %	0.28	0.64	0.80	0.67	
Margins, \$	20.05	19.00	30.00	26.67	
Quantity, tonnes	150	0	185	465	
Revenue, \$	3007.24	0.00	5543.47	12405.80	
Wheat C, tonnes	500		Opt Rev.	20956.51	
Production, tonnes	800				
			Min	Max	Select
	Wheat C		100	500	500.0002
	Blend 1		0	150	150
	Blend 2		0	100	0
	Blend 3		0	400	185
	Blend 4		0	600	465
	Production		800	900	800



OPTIMIZATION OF MULTIPLE BLENDS

INFEASIBLE SOLUTION

	Blend 1	Blend 2	Blend 3	Blend 4
Cost of blend per tonne, \$	389.95	396	420	433.33
Wheat C, %	0.28	0.64	0.80	0.67
Margins, \$	20.05	19.00	30.00	26.67
Quantity, tonnes	150	100	200	350
Revenue, \$	3007.24	1900.00	6000.00	9333.33
Wheat C, tonnes	499	Opt Rev.		20240.57
Production, tonnes	800			
			Min	Max
	Wheat C		100	400
	Blend 1		0	150
	Blend 2		0	100
	Blend 3		200	400
	Blend 4		0	600
	Production		800	900



OPTIMIZATION OF MULTIPLE BLENDS

FEASIBLE SOLUTION

	Blend 1	Blend 2	Blend 3	Blend 4	
Cost of blend per tonne, \$	389.95	396	420	433.33	
Wheat C, %	0.28	0.64	0.80	0.67	
Margins, \$	20.05	19.00	30.00	26.67	
Quantity, tonnes	150	0	197	353	
Revenue, \$	3007.24	0.00	5918.47	9405.80	
Wheat C, tonnes	435		Opt Rev.	18331.51	
Production, tonnes	700				
			Min	Max	Select
	Wheat C		100	435	435.0002
	Blend 1		0	150	150
	Blend 2		0	100	0
	Blend 3		0	400	197
	Blend 4		0	600	353
	Production		700	900	700