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Evaluation of Four Australian Bread Wheat Varieties Grown Under Centre Pivot Irrigation System

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ABSTRACT:
Three years of field trials were conducted in 2004 – 2006 on four Australian hard white wheat varieties and the local hard red spring wheat Yecora Rojo variety grown under Centre pivot irrigation system. These trials' object was to evaluate the possibility of localizing these varieties' cultivation at TADCO, Saudi Arabia, to process good quality bread, hard pastry, and noodles.
Laboratory tests have shown the grains of Yecora Rojo was higher than the Australian varieties grains in terms of % crude protein, % wet gluten, and the difference in crude protein is around 1.7%. Results have shown that as productivity was increased, % crude protein, % wet gluten, and Zeleny value was decreased. Zeleny's value is the measure of gluten quantity and quality; Zeleny's general average on Kennedy grains in the three cropping seasons reached 48.13. This was higher than Australian wheat varieties that ranged 30.53 – 33.13. The falling number on Kennedy, Drysdale, and Giles was very high, an indication of strong flour dough, and on Lang, it was medium, an indication of medium dough strength. The Australian wheat varieties' flour color was brilliant white at 70 and 80% extractions except for Drysdale at 80%. It was less white.
The three years trials had shown the productivity of these varieties matched the productivity of Yecora Rojo with an average of 8.07 M.T. /Ha when the varieties were grown under favorable local conditions. Field, Laboratory, Silos, and Bakeries tests shown three varieties Kennedy, Lang, and Drysdale were found suitable for wheat production and food processing. Giles need further blending tests with the chosen varieties for food processing.

Keywords: *Wheat Productivity, Crude Protein, Zeleny Value, Falling Number, Grain and Flour Analyzer, Farinograph*..

I. INTRODUCTION

Wheat is a major food resource for most countries globally as it provides more nourishment for humans than any other food source. Wheat is the largest crop grown globally as the cultivated area reaches more than 240 million Hectare, and its trade volume is greater than all other crops combined. The major cultivated areas of wheat crops are dependent on rainfall, which affects its yield, which fluctuates annually depending on the amount and duration of rain [1].

Over the last decade, cultivated wheat areas under irrigation systems increased significantly due to increased demand for the wheat commodity to satisfy the increased world population. The productivity per unit area is higher than in rain-fed areas by 2-3 folds. Irrigated Wheat is practiced in the center of Asia: Pakistan, northwest of India, Nepal, northern Bangladesh, Afghanistan, south-central of China, and parts of West Asia: Iran, Turkey, Syria, Iraq, and Saudi Arabia [2]. Irrigation of wheat crop using Centre pivot irrigation system is practiced as subsidiary to annual rainfall in countries like the USA and South Africa and as the main source of irrigation water in counties with a dry climate like Saudi Arabia, Mexico, and Egypt. In Saudi Arabia, the dwarf hard red spring crop cultivation, mainly Yecora Rojo variety, increased rapidly after 1979 and reached an area of around 630.000 ha with an estimated production of 2,544,300 M.T. in 1986 [3].

Tabuk agriculture development company (TADCO) was one of the leading Saudi companies on wheat production under the Centre pivot irrigation system. They achieved high yields above 8 M.T. /Ha during the period 2001 – 2011, and in the 2003 season, the average wheat production of an area over 5000 Hectare reached 8.73 M.T. /Ha. TADCO was specializing in producing certified wheat seeds to the Saudi farmers with average annual sales of around 20000 - 30000 M.T. in place of TADCO strategy to test new varieties of bread wheat of high productivity and promising technological qualities. The company tested during the period 2000 – 2009 different bread wheat varieties in coordination with the Seeds Producers Committee (SPC) and the Saudi Ministry of Agriculture (MOA) to get new varieties of desired quality to the end-user. In 2001/2002 cropping seasons, the TADCO research unit tested eight American bread wheat varieties under code numbers 81470 to 81477 and five hard white bread wheat varieties from the

Ministry of Agriculture in Riyadh: Tia, Kauz, Irena, Parus, HD-2329 [4]. In 2008 and 2009, the research unit conducted trials on 29 elite bread wheat selections (3rdEBW) from the CIMMYT brought from the MOA.

In response to meeting the desire of a wide segment of consumers in the Kingdom of Saudi Arabia who demanded Dubai flour produced from a mixture of Australian wheat varieties. TADCO and through the Australian irrigation consultant working for the company Mr. Grant Stuart contacted Australian companies exporting wheat grains to the Middle East region in the mid-summer of 2003, where they requested to test varieties of the hard white Wheat used in the manufacturing of various kinds of bread, hard pastries, and noodles in Saudi Arabia and GCC countries. The selection fell on four varieties of Wheat belonging to two Australian companies. They imported a quantity of 2.3 tons of each variety in November 2003, sufficient to cultivate 12.5 hectares of each variety under the Centre pivot irrigation system in the 2004 season. The trial was designed to be repeated in the next two seasons, 2005 and 2006, to get a large bulk of grains for technological testing by the government silos and local bakeries.

This article reviews research work carried out at TADCO by the authors on Australian wheat varieties during 2004 – 2006. This study aimed to localize the cultivation of Australian hard white wheat varieties suitable for processing good quality bread, pastry, and noodles.

II. MATERIALS & METHODS

A. Land Preparation & Sowing: One pivot J08P50 was chosen to test growing the four Australian bread wheat varieties; this pivot was cultivated with alfalfa in the previous two seasons, 2002 and 2003. Start pre-irrigation on the 14th of December, 2003 for two rounds of irrigation at a speed of 20% with a total amount of 46.3 mm to encourage the regrowth of alfalfa ratoons one-week spray Touch Down 48% at a rate of 6 liters per Hectare. Wait 14 days for the herbicide to affect the alfalfa, then broadcast NPK granular fertilizer 14-38-10 at a rate of 280 kg/ha followed by two rounds of 80% irrigation to soften the soil surface before sowing the seeds of each variety in one-quarter of the pivot by direct drilling using the Rapid Vaderstad No-Till planter on the 20th of January, 2004 at a seed rate 195-200 kg/ha. Late sowing was due to the late delivery of the wheat seeds.
The trial was repeated on the same pivot J08P50 in 2005 cropping season: pre-irrigation of two rounds irrigation at 20% with a total amount of 46.3 mm, then wait for two weeks to encourage the germination of old wheat seeds and weeds. Then irrigate for two passes of irrigation with a total 12 mm followed by cross chisel plow to a depth of 15 to 25 cm in the opposite direction (45º angle) cultivation followed by pipe leveling. Granular NPK fertilizer was broadcasted at a rate of 280 kg/ha. Seeds sowing was carried out on the 23rd of December, 2004 using a John Deer drilling machine. Each variety was sown in the pivot at the same location as the previous season and the same rate of the 2004 season.
The trial was repeated in the third season 2006 by allocating one pivot of 50 ha for each wheat variety; J21P25 for TADCO 4, J27P08 for TADCO 5, J29P02 TADCO 7, and J43P88 for TADCO 8. Land preparation, fertilizer application, and sowing were carried out similar to the procedure in the 2005 season; the pivots were sown during the period 1st to 3rd of January 2006.

B. Trials Layout: The trial pivot J08P50 was divided into four sections before sowing the seeds through the arrangement of two crossing roads passing the center of the pivot. Each section was allocated for each variety with an area of 12.5 ha. The varieties were identified by the following symbols to distinguish them from each other: TADCO 4 for Giles, TADCO 5 for Kennedy, TADCO 8 for Lang [5], [6], [7] and TADCO 7 for Drysdale [8]. The varieties were planted separately to preserve the varieties' purity by preventing mixing with each other or mixing with the prevailing Yocora Rojo variety in the company fields. For the convenience of following this research work, we used the actual names in this review.

C. Crop Maintenance: The Grains Production personnel carried out daily activities for wheat crop maintenance. It involved irrigation, fertilizer application, pest and disease control, and supervision of crop harvest, transportation, and storage. The different varieties were harvested separately from each other. The grains of each variety were packed into jumbo bags of one-ton capacity and kept in its warehouses.
Broadleaves weeds and grasses infestations were controlled at the 3–5 leaf stage by spraying a mixture of herbicides (Topic 0.3 L + Banvel 0.175 L + Broadstrike 25 gram /Ha). Control of pests and diseases such as aphids, leaf miner, and protection form foliage diseases was carried out through the injection of pesticides with the irrigation water: Dimethoate insecticide 1.5 L/ha mixed with fungicides Tilt 0.6 L + Carbendazim 1 L/ha Urea of a total quantity 360 kg/ha was injected with the irrigation water on weekly doses during the growing season. A top-dressing of the whole planted pivot with granular NPK fertilizer 14-38-10 at a rate of 220 kg/ha plus granular potassium sulfate fertilizer 200 kg/ha after herbicide spraying program 45 – 60 days after sowing. It was estimated that the amount of irrigation water consumed through the growing season per Hectare was about 1100 mm, including pre-irrigation of about 80 - 105 mm before sowing. One mm equals 10 M^3/ha.

D. Wheat Varieties Profile:

Yecora Rojo: It is classified as hard red spring wheat and characterized as awned, white chaff, short, stiff straw, early maturing, good resistance to lodging. Productivity in the Tabuk area ranged from 7 – 9.5 M.T. /Ha, and it proved to be resistant to rust and smut diseases under local conditions. The grains of this variety contains high % crude protein, and it ranged 12 – 15%, very strong dough, with good

extensibility, very good for bread baking. It was the dominant bread wheat variety grown under the Centre pivot irrigation system in all agricultural areas of Saudi Arabia.

The characters of the **Australian wheat varieties** [5], [9], [10], which are considered as hard white wheat varieties, are shown in the following table:

Comparison	Australian Varietal Characteristics			
	Giles	Kennedy	Drysdale	Lang
Pedigree	Jauz/Vulian	Hartog/Very # 5	CSIRO	QT3765/Sunco
Royalty	Yes	Yes	Yes	Yes
License	Plant-Tech	AWB Seeds	AWB Seeds	AWB Seeds
Released by	QDPI 1999	QDPI 2000	CSIRO	QDPI 2000
AWB Classification	APH	APH	APH	APH
Awned	Yes	Yes	Yes	Yes
Sprouting Resistance	ok	2	ok	3
Black Point	4	5	High	7
Straw Strength	6	6	6	5
Shattering	7	7	7	7
Stem Rust	8	8	High	7
Leaf Rust	8	6	High	5
Stripe Rust	7	7	High	7
Common Root Rot	4	4	High	6
Lesion Nematode	6	4	High	6
Maturity	Slow	Quick	Quick	Intermediate
Australian Millers Characteristics				
Bin Code	APH2, H2	APH2, H2, APW2	AH, APW	APH2, H2, APW2
Quality Rating	3 Poor extensibility, high dough strength, average baking quality	6 High dough strength, long mixing time, excellent baking quality	4 Acceptable extensibility, High dough strength, long mixing time, medium baking quality,	6 High dough strength, long
APH; Australian Prime Hard APW: Australian Premium White ASW: Australian Standard White AWB Australian Wheat Seeds Co.			APH2: Yellow alkaline noodles and Bread H2: Plant Bakeries APW2: Retail Products and pastry	

N.B. The quality rating is determined on a scale of 0 – 9. The higher the rating, the better quality for particular varietal end users.

E. Data Recording*:* To compare the different varieties with each other and with the local variety Yecora Rojo: research personnel was directed to monitor the pivot trial J08P50 during the growing season and collect grains samples after harvest to study the agronomic and quality characters of the varieties. For the agronomic characters, they recorded the following data: number of plants/M^2, number of tillers/plant, spike length, Plants height, number of seeds/spike, number of days for 50% heading, date of maturity, 1000 grains weight (TGW) & productivity of each variety M.T./Ha, disease incidence, resistance to lodging, resistance to shattering, %black point. For the varieties' quality characters, each season's grain samples, each 2 kg, were collected and sent to the TADCO lab for grains and flours analysis using Grain and Flour Analyzer Infratec 1241. The lab conducted the following tests on the grains samples: test weight, %crude protein, %moisture Content, %starch, %wet gluten, Zeleny test, and manually conduct TGW, % black point tests. Another part of the grains sample of each variety was milled to get flour sample and conduct the following tests: %crude protein, %moisture Content, %ash, %wet gluten, and %water absorption.

The whole wheat production of the four Australian wheat varieties of a total quantity of 720 M.T. was dispatched to the government silos in Tabuk on the 25th of April, 2006 to conduct technological testing on the flour of the grain of each variety. For this object, we followed Farinograph tests at the Silos Laboratory; the Farinograph is a tool used to assess flour doughs' baking qualities and performance. We monitored and recorded the analysis results on the dough samples of 70 and 80% flour extraction conducted on the wheat varieties produced in the 2004 and 2005 cropping seasons.

We also collected flours samples of the different Australian wheat varieties at 70, 80, and 100% flour extractions analyzed by the TADCO laboratory.

F. Description of Grain & flour samples analysis: we receive the cleaned and labeled wheat grains samples, and then we record in the logbook with the corresponding laboratory number. Operate the Grain & Flour Analyzer Infratec 1241 [11] for a free heating and self-checking the software of about 20-25 minutes. Select the software module for the respective grain analysis: WH–182126 for Wheat, WF–033754 for wheat flour, WF–440010 for high ash flour. Take around 800-gram samples of wheat grains filled in a glass beaker and pour it in the hopper of the apparatus. Enter the sample number on the screen, follow the highlighted command options, and finally press the enter key for analysis. The sample is transferred, scanned into the machine automatically. Within 50 seconds, the analysis is completed, and the results are displayed on the screen for the following parameters: %Protein, %Moisture Content, %Starch, %Wet Gluten, Zeleny value & Test Weight kg/hl. A batch of samples could be tested using this method; the

Figure 1. Grain and Flour Analyzer Infratec 1241

The results of 50-60 samples could be copied from the instrument's software into a storage desk and entered into the computer to edit and prepare the report. For flour samples analysis, we take around a 125-gram sample, fill it in the sample cell (cup), and then follow the same grain analysis procedure. The flour samples analysis results displayed on the screen are %Protein, %Moisture Content, %Ash & %Gluten.

Testing the validity of NIR analysis results: we checked the lab analysis results on wheat grains samples for %crude using the wet method (Kjdahl method). We compared it with the analysis results using the Grain and Flour Analyzer (NIR method) shown in the following

Table 1:

Analysis Method	% Crude Protein Samples					Mean
Kjeldahl	12.76	13.56	13.96	15.96	16.35	15.39
	16.36	15.76	16.15	17.15	15.96	
NIR Method	12.62	13.41	14.06	16.58		15.51
	16.68	15.86	16.57	16.92	15.75	

Statistical analysis using a paired T-test shown no significance

The difference between the two methods as the observed t value was 1.22. The standard error was 0.0936, which was lower than the value in the t table.

***G. Testing the baking* qualities** [12]: we arranged in June 2006 with two bakeries at Tabuk city for testing two flour extractions 70 and 80% of the Australian varieties in the presence of TADCO and Silos committee to assess the qualities of different bread products. The procedure at Bakery A for making flatbread from the 80% flour extract of Kennedy and Giles varieties. They transferred two bags of flour into the dough container, and each bag was 40 kg, then prepare the dough with the addition of water and yeast. Stir the mixture for 25 minutes until the dough preparation was completed. Prepare small dough pieces, flatten it as a round-shaped loaf of 30 cm diameter and place it on a moving elevator in preparation for baking. Wait 90 minutes for the fermentation process at around 40º C in the bakery, then manually send the flat round pieces into the oven. Remove the loaves from the oven after baking.

The procedure at Bakery B for making toast bread (white pan bread) from the 80% flour extract of Lang and Drysdale varieties. They transferred half a bag (20 kg) of flour into the dough container, and they added oil, yeast, milk, sugar, salt, then mix with the appropriate amount of water. Stir the mixture for (15) minutes until the dough preparation was completed, cut the dough into small pieces, and place them for some time on shelves to aid fermentation. Transfer the dough pieces to special molds for toast making and place them into a room saturated with steam for 45 minutes to help the dough to swell at 37 Cº incubation temperature. Transfer the molds into the oven for baking. After baking, the bread, loaves were removed from the molds and left on trays to cool down in the open air. Cut the loaves into slices with a cutting machine. For Samuli bread preparation from 80% flour extract, they transferred half a bag (20 kg) of flour into the dough container with water, yeast, and improver to prepare the dough. Cut the dough into small pieces of equal rectangle pieces and place them for 40 minutes on shelves to aid fermentation. Transfer the dough pieces to special trays and place them into a room saturated with steam for 75 minutes to help the dough to swell at 37 Cº incubation temperature. Transfer the trays into the oven for baking. After baking, the trays were left to cool down in the open air. A similar method to Bakery A was followed in this bakery for the preparation of Arabic Flat Bread.

III. RESULTS & DISCUSSION

A- Agronomic Characters:

Summary of the important agronomic characters of the Australian varieties [5], [7], [8], and Yecora Rojo in relation to productivity in the 2006 cropping season are presented in **Table 2**. We observed the following:

1-Plant height: All of the varieties were short, and Yecora Rojo was the shortest with 90 cm height; the Australian varieties were with almost similar height, which ranged 96.08 to 97.1 cm. It is desired to get a dwarf variety to overcome the lodging problem.

2- Number of tillers/Plant: The number of tillers/plant ranged from 3.4 – 4.76, and these were significantly higher than Yecora Rojo with 2.4 tillers/plant. Giles and Lang were the highest at 4.76. 4.65 tillers/plant followed by Kennedy then Drysdale with 3.5, 3.4 tillers/plant, respectively.

3- Number of days for 100% heading: We observed the earliest heading variety was Kennedy with 98 days, followed by Yecora Rojo and Drysdale with 100 days, then Lang and Giles with 112 days. It is desired to get an early heading variety to save energy & water.

4- Number of spikes/M²: Due to high-density planting at a seed sowing rate of 195-200 kg/ha, the number of tillers that succeeded in producing spikes was low. The number of spikes on Kennedy was the lowest with 452/ M² and the rest

Table 2. Summary on important agronomic characters of Australian bread wheat varieties and Yecora Rojo in 2006 cropping season.

Plant Measurement	Bread Wheat Variety				
	Giles	Kennedy	Drysdale	Lang	Yecora Rojo
Plant Height (cm.)	97.1	96.8	96.4	96.1	90
Number of tillers/plant	4.76	3.5	3.4	4.65	2.4
Number of days for 100% Heading	112	98	100	112	100
Number of Spikes/M^2	621	452	497	600	650
Number of seeds/spike	56	59.2	57.8	56.0	59.0
Length of spike	8.43	9.10	9.32	8.44	10.2
Thousand grains weight	33.4	38.1	41.6	34.5	44.3
% Lodging vs total area	45%	0.001	0.001	0.001	5 – 10%
Potential Yield M.T./Ha	8.31	8.97	8.92	8.24	9.52

Of the varieties were with a reasonable number of spikes/ M^2, which ranged 497 – 650. The number of spikes/M^2 is an important parameter affecting the potential yield of a particular variety, and it is desired to get a variety with more spikes / M^2.

5- Length of spike:: All of the varieties were with medium spike length, but Yecora Rojo was with a spike length of 10.2 cm, which was slightly taller than the Australian varieties, ranging from 8.43 9.32 cm. Increased spike length leads to more seeds/spike, and this is an indicator of higher yield.

6- Number of seeds/Spike: It is an important parameter affecting a particular variety's potential yield. We observed all of the varieties were with a medium number of seeds/spike, which ranged 56 – 59 seeds/spike.

7- One Thousand Grains Weight (TGW): This is a measure of specific weight; increased TGW indicates good grains quality. Drysdale was with a TGW value of 41.6 grams, and this
was significantly higher than other Australian varieties, which ranged from 33.4 to 34.5 gram; Lang was with the lowest TGW, which reached 30.4 gram. Yecora Rojo was with the highest TGW value, with 44.3 grams. TGW value is an important parameter affecting the potential yield of a particular wheat variety.

8- Lodging Resistance: We observed around 45% of Giles plants were lodged, while other Australian varieties' negligible plants were lodged. Any factor which leads to the development of a weak root system or weak anchorage of the roots with the soil or weak stem base leads to plants lodging. These factors are tall plants, high density of sowing, excessive nitrogen fertilizer application, infection with root diseases, strong wind blowing. Giles variety was lodged due to the high sowing rate combined with high nitrogen application, which leads to lodging under the effect of a strong wind blowing.

9- Potential yield: The yield of a particular wheat variety grown under the local favorable growing conditions with negligible pests, diseases, weeds, and lodging. The potential yield of a particular variety M.T. /Ha is a product of the number of spikes/M^2 multiplied by the number of grains in the spike times the weight of one thousand grains (grams) divided by 100000. The Australian varieties' potential yield was 8.97, 8.92, 8.31, and 8.24, M.T. /Ha for Kennedy, Drysdale, Giles, and Lang. The potential yield of Yecora Rojo was 9.52 M.T. /Ha, and this was higher than the Australian wheat varieties.

No serious wheat disease such as rusts, smuts, Septoria, etc. was observed on the Australian wheat varieties during the trials period.

***B- Productivity*:**

The productivity of the Australian wheat varieties [5], [7], [8], along with Yecora Rojo in the three cropping seasons 2004, 2005, and 2006 is presented in **Table 3** and **Figure 2**. The average productivity of the varieties at J08P50 in the first cropping season 2004 was 7.28 M.T. /Ha, and this was less than in the 2005 and 2006 cropping seasons due to the delay in the date of sowing after a late delivery of the seeds. The productivity of the varieties in the 2005 cropping season was increased significantly at the same pivot J08P50 due to optimum growing conditions regarding date of sowing, optimum irrigation with 850 GPM, optimum nutrition with NPK + trace elements + urea, pests, and diseases control. As a result of that improvement, the yield of the three Australian varieties Giles, Drysdale, and Lang, was 8.31, 8.06, 8.68 M.T. /Ha, respectively. However, Kennedy variety produced 7.28 M.T. /Ha in 2005, which was higher than the 2004 season. Still, it was less than the other varieties due to its unlevelled location sector with loamy sand soil. In the 2006 cropping season, Kennedy's productivity was improved at J27P08, and its yield reached 8.04 M.T. /Ha, which was higher than the other three varieties due to shortage of irrigation requirements on the wells of the corresponding pivots as it was dropped to less than 700 GPM at J29P02.

In comparison, the Australian varieties' productivity in the three seasons occasionally reached above 8.0 M.T. /Ha.

When they were cultivated under optimum growing

conditions, this matched Yecora Rojo's productivity, which reached a general average of 8.07 M.T. /Ha on all TADCO pivot areas ranging from 6525 Ha in 2004 to 7165 Ha in 2006. Lang variety produced the highest yield in 2004 and 2005 seasons with 8.17, 8.68 M.T./Ha, respectively, while Giles and Drysdale's varieties produced high yield in 2005 compared to other seasons.

Table 3. Comparison of four Australian bread wheat varieties' productivity with Yecora Rojo grown at TADCO in three cropping seasons 2004 - 2006.

Cropping Season/Area (Ha)	Date of Sowing	Date of Harvest	The productivity of wheat varieties M.T./Ha					Mean Yield/ M.T./ Ha
			Giles	Kennedy	Drysdale	Lang	Yecora Rojo	
2004 (50 Ha)*	24/1/04	8/7/04	7.4	6.17	7.39	8.17	8.1	7.28
2005 (50 Ha)*	23/12/04	27/6/05	8.31	7.28	8.06	8.68	8.0	8.08
2006 (200 Ha)	1-3/01/06	27/6/06	7.83	8.04	6.94	7.78	8.1	7.65
Pivots in 2006			J21P24	J27P08	J29P02	J43P88	147 Pivots	
Area (Ha)			50	50	50	50	7156	
General Mean Yield M.T,/Ha			7.84	7.16	7.48	8.21	8.07	

* Each variety 12.5 Ha at J08P50.

The overall results, Lang yield, was the highest as it reached 8.21 M.T./ha followed by Giles then Drysdale then Kennedy with average productivity of 7.84, 7.48. 7.16 M.T. /Ha, respectively.

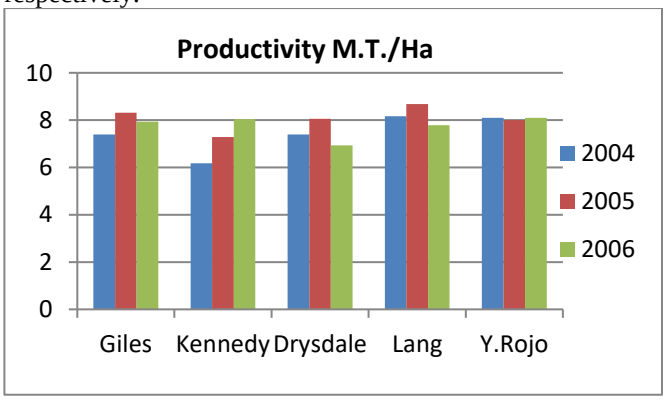

Figure 2. Comparison of four Australian bread wheat varieties' productivity with Yecora Rojo grown at TADCO in three cropping seasons 2004 - 2006.

C- Grains Quality [12], [13]:

The research work was directed to study the factors governing the physical and chemical properties affecting the wheat varieties' milling and baking qualities. The laboratory analysis results of cleaned grains samples of four Australian bread wheat varieties along with Yecora Rojo variety produced in the three cropping seasons 2004, 2005, and 2006 are presented in **Table 4. W**e observed the following:

1-% Crude Protein: The wheat grain contains 8 - 17% protein according to the genotype and the external factors related to the crop. The % crude protein in the 2004 season was almost similar for the Australian varieties, which ranged between 13.34 – 13.48%, and this was less than the protein content on Yecora Rojo, which reached 14.82%. The average % crude protein of the Australian varieties over the three seasons was 12.39%, and this was less than Yecora Rojo with 14.10%.

Comparing the Australian varieties results into the three seasons showed high protein content in the 2004 season with an average of 13.44%, which was higher than in 2005 with 12.36%, see **Figure 3** and **Table 4**.

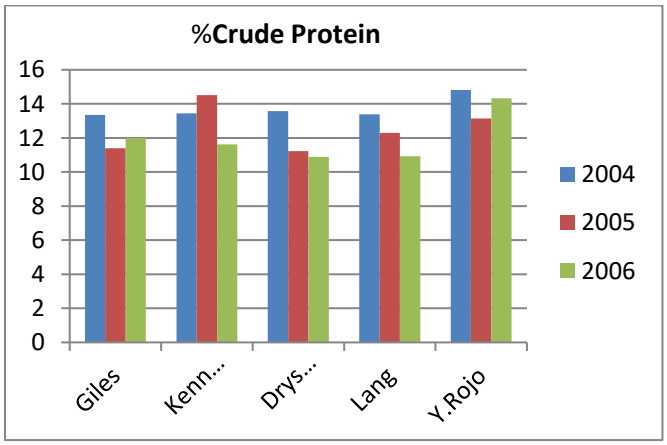

Figure 3. % Crude protein of four Australian bread wheat varieties and Yecora Rojo in three cropping seasons 2004, 2005, and 2006.

High yield of Giles, Drysdale, and Lang in the 2005 season lead to less crude protein than the 2004 season; also, less yield of Kennedy in 2005 led to high %crude protein with 14.52%. In 2006, the average crude protein on the Australian wheat varieties dropped to 11.36% due to a shortage of irrigation water. Kennedy's average crude protein over the three seasons reached 13.20%, and this was higher than Giles, Lang, and Drysdale varieties with 12.25, 12.20, 11.90%, respectively. Increased % crude protein in the grains of the varieties was an indication of high grains quality

Table 4. Laboratory analysis results on the grain samples of four Australian bread wheat varieties and Yecora Rojo in three cropping seasons 2004, 2005, and 2006.

Cropping Season	Type of Analysis	Bread Wheat Variety					
		Giles	Kennedy	Drysdale	Lang	Mean for Australian Varieties	Yecora Rojo
2004	%Crude Protein	13.34	13.45	13.57	13.48	13.44	14.82
	% Moisture Content	5.72	6.01	5.81	5.67	5.72	6.57
	% Starch	65.8	64.7	65.4	65.8	65.42	64.1
	% Wet Gluten	27.8	27.6	28.4	26.8	27.65	28.45
	Zeleny Test	37.0	41.9	42.3	40.1	40.33	47.0
	Test Weight	83.5	81.0	82.2	83.4	82.53	80.25
	% Black Point	4.01	0.00	1.07	0.77	1.46	4.83
2005	%Crude Protein	11.4	14.52	11.23	12.3	12.36	13.15
	% Moisture Content	5.71	5.75	5.94	5.85	5.71	5.81
	% Starch	66.3	64.2	66.3	65.5	65.57	65.58
	% Wet Gluten	25.4	25.5	25.9	25.3	25.53	25.53
	Zeleny Test	27.0	54.2	23.6	32.2	34.25	34.25
	Test Weight	83.2	78.6	84.7	83.0	82.38	82.38
	% Black Point	1.8	0.11	0.68	1.34	0.98	0.98
2006	%Crude Protein	12.0	11.63	10.89	10.93	11.36	14.32
	% Moisture Content	5.99	6.28	6.3	6.34	6.14	6.29
	% Starch	65.9	65.1	66	66.6	65.90	65.84
	% Wet Gluten	25.6	25.2	25.4	25.5	25.43	27.55
	Zeleny Test	31.0	33.3	25.7	27.1	29.28	42.17
	Test Weight	81.8	81.0	82.6	81.8	81.80	83.46
	% Black Point	2.32	0.68	0.8	6.76	2.64	2.34
Average of All Cropping Seasons	%Crude Protein	12.25	13.20	11.90	12.20	12.39	14.10
	% Moisture Content	5.8	6.01	6.02	5.95	5.81	5.92
	% Starch	66.0	64.7	65.9	65.97	65.63	65.17
	% Wet Gluten	26.27	26.1	26.57	25.87	26.20	27.18
	Zeleny Test	31.67	48.13	30.53	33.13	34.62	41.14
	Test Weight	82.83	80.2	83.17	82.73	82.24	82.35
	% Black Point	2.71	0.26	0.85	2.96	2.82	2.71

2- % Moisture Content: The water content of the grains affects the degree of preservation during storage. If the seeds contain more than 14% moisture content, this leads to their infection with molds. The % moisture content ranged from 5.71 to 6.34%, which was low on all of the varieties due to dry weather in Saud Arabia at the time of harvest.

3- % Starch: Wheat grain contains 63 - 71% starch in the form of amylose and amylopectin. The percentage of starch has little effect on the flour's functional properties, but mixing it with other ingredients of bread significantly affects the water absorption process and the fermentation time to make the dough and the structural characteristics of the bread crumbs and its dryness. The grains analysis results showed that the % starch ranged from 64.1 to 66.6% which was relatively low on all varieties. Giles was the highest with an average of 66.0%, followed by Lang, then Drysdale, then Yecora Rojo, then Kennedy with an average of 65.97, 65.9. 65.17, 64.7% respectively.

4- Wet Gluten: Wet Gluten provides a quantitative measure of gluten forming protein in flour that is primarily responsible for its mixing and baking properties. Gluten is not dissolved in water, but it takes a sticky and elastic form; the grain endosperm contributes 78-85% of the gluten content. Wheat gluten consists of two main components: glutenin, which is characterized by flexibility, and gliadin, which is characterized by stickiness and elasticity. The grains analysis results shown % wet gluten ranged from 25.2 to 28.45%. We observed relatively high % wet gluten on the Australian varieties in 2004 with 27.65%, and this was due to high % crude protein in the 2004 season compared to the

2005 season. The % wet gluten in 2005 and 2006 on the Australian varieties was relatively low with similar values, which ranged 25.2 – 25.9. The average % wet gluten of the Australian varieties over the three seasons was 26.20%, and this was slightly less than Yecora Rojo, with an average of 27.18%. Increased % of wet gluten was an indication of high grains quality.

5- Zeleny Test [12]: This test measures the quality and quantity of gluten. As mentioned earlier, the components of wheat gluten are glutenin and gliadin: glutenin is the largest part of gluten and is characterized by flexibility and is responsible for the dough's strength. The other smaller part, called gliadin, is sticky and elastic and is responsible for giving bread the ability to rise properly during baking. High Zeleny value indicates an increase in the flour content of glutenin at the expense of gliadin, indicating an increase in the dough strength measured by the Farinograh. The results of the Zeleny test on the bread wheat varieties are presented in **Figure 4**; it ranged from 23.6 to 54.20. We observed a high Zeleny value on the Australian varieties in 2004, with an average of 40.33. This was high due to high % crude protein in the 2004 season compared to the 2005 season; also, Zeleny value on Kennedy in 2005 was very high with value 54.2 due to high %crude protein. In 2006, the Zeleny value of the Australian varieties was relatively less, which ranged 25.7 – 33.3; the average Zeleny value of the Australian varieties over the three seasons was 34.62, and this was less than Yecora Rojo with a value of 41.14.

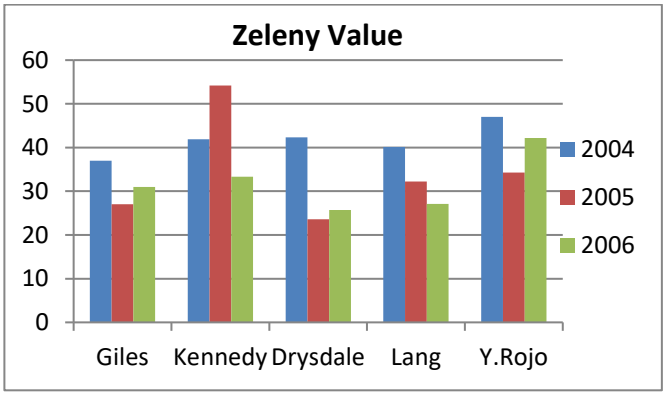

Figure 4. Zeleny value of four Australian bread wheat varieties and Yecora Rojo in three cropping seasons 2004, 2005, and 2006.

6- Test Weight: It is a measure of specific weight, and it is considered an indicator of wheat grain's quality. The grains analysis results shown test weight ranged from 81.0 to 84.7 kg/hl, which is good. The highest average test weight was on Drysdale with 83.17, then Giles then Lang then Yecora Rojo, then Kennedy with 82.83, 82.73, 82.35, 80.2 kg/hl, respectively.

7- % Black Point: It is defined as the black color on the wheat grains' embryo tip due to the wheat crop's late irrigation. This affects the quality of durum wheat directed for semolina. The results on the %black point of the bread wheat varieties ranged from zero to 6.76 %. The lowest %black point average was on Kennedy with 0.26%, then Drysdale with 0.85%, then Yecora Rojo and Giles, each with 2.71%, then Lang with 2.96%.

D-Analysis of the Grains samples in Dubai Milling Lab [13], [14]:

The results of the analysis of the grains samples sent to the Dubai Lab are presented in **Table 5**. We observed the following:

1- % Moisture Content: The percentage moisture content in the grains ranged between 7.49 - 7.98%, which is slightly higher than the moisture content of Yocora Rogo grains with 6.68%, and these were low due to the dry climate in Saudi Arabia at the time of harvest.

2- Test weight: It ranged between 80.1 - 82.30 kg/hectoliter, and these were slightly higher than Yecora Rojo; the highest test weight value was on the grains of Drysdale with 82.3 kg/hl, followed by Lang with 82 kg/hl, then Giles with 80.20 kg/hl then Kennedy with 80.1 kg/hl and finally Yecora Rojo with a value of 79.40 kg/hl.

3- Thousand Grains Weight: It was noted that this value ranged 38.4 - 46.4, and high values are preferred. Drysdale grains were the highest with 46.40 grams, followed by Yecora Rojo with 44.2 grams, then Kennedy 41.3, then Lang with 39.4, and finally Giles with 38.4 grams.

4- Particles Size Index (PSI) [15]: This parameter measures the relative hardness of the grains depending on the particles' size after milling and sieving. The grain's hardness is attributed to the grains' resistance to breakage when producing flour, semolina, or bulgur. It is a qualitative characteristic that affects technological characteristics when milling and when baking. Solid grains need a longer time and more energy to complete the milling process, and it produces a large amount of flour affected by the process. The lab measured the grains' hardness based on the distribution of the particles according to their size. It was observed that the grains of Drysdale were the hardest with psi 9.5, followed by Yocora Rogo with 9.6, then Kennedy with 10.1, then Lang with 11.02, and finally, Giles grains were the lowest with psi 13.3. According to these results, the wheat varieties kernels were classified as very hard except Giles kernels were hard.

5- Screening Test: This test measures the degree of grains health as per the exposure to environmental factors such as rain and drought or biological factors such as fungal and insect infestation or contamination with weed seeds or exposure to breakage during harvesting, transportation, storage, or mixing with gravel and dust, etc. The percentage of excluded grains in high-quality grains ranges from 2-5%.

Table 5. Analysis results on four Australian bread wheat grains samples and Yecora Rojo at the milling lab in Dubai on the 1st of November, 2004.

Type of Analysis	Units	Varieties Samples					
		Yecora Rojo	Giles	Kennedy	Drysdale	Lang	Acceptable Level
Grains Test							
Moisture	%	6.68	7.98	7.49	7.58	7.62	5 – 14
Test Weight	Kg/HL	79.4	80.2	80.1	82.3	82	> 76
TGW	Gram	44.2	38.4	41.3	46.4	39.4	> 38
Particles Size Index	Pounds	9.6	13.3	10.1	9.5	11.2	8–12 Very Hard
Total edible screening	%	2.90	4.92	0.62	4.32	2.7	
Total non-edible screening	%	0.1	0.05	0.00	0.00	0.05	
Total Screenings	%	3	4.97	0.62	4.32	2.75	< 5%
Flour Tests							
Falling Number	Seconds	586	483	551	533	479	300 - 600
Ash (D/B)	%	1.87	1.78	1.82	1.93	1.75	1.5 - 2
Protein (11% MB)	%	13.52	12.33	12.85	13.18	12.51	
Protein (D/B)	%	15.19	13.85	14.44	14.81	14.06	> 12

It was observed that the percentage of excluded grains on Kennedy was very low with 0.62%, which indicates very clean grains followed by Lang then Yecora Rojo, then Drysdale then Giles with 2.75, 3.0, 4.32, and 4.97% respectively. These results indicate that all of the grains' samples were clean.

6- % Ash: The percentage of ash represents mineral elements in the flour, and it is an indicator of flour extraction. It was estimated based on the dry weight in the flour of the milled grains samples; the % ash ranged 1.75 - 1.82%, which was within the acceptable range for wheat grains on a dry basis before flour extraction.

7- % Crude Protein: It was estimated at a moisture content of 11% in the grains' flour, where it ranged 12.51 - 13.18%, which is slightly less than the protein content on Yecora Rojo, which reached 13.52%. The highest protein content was on Drysdale, reaching 13.18%, followed by Kennedy with 12.85%, then Lang with 12.51%, and finally, Giles with 12.33%.

8- Falling Number [16], [17]: It is a measure of the alpha-amylase enzyme activity in the flour of the grains. It was observed that the best varieties were Yecora Rojo with a falling time of 586 seconds, followed by Kennedy with a time of 551 seconds. With a time of 533 seconds, Drysdale followed by Giles with a falling time of 483 seconds and finally Lang with a falling time of 479 seconds. According to the falling time results, all of the varieties were suitable for making Arabic bread.

E- Flour Quality [18], [19]:
For this object, we conducted laboratory analysis on the flour samples of 70, 80, and 100% extraction, which was collected from Tabuk silos after milling the shipment of the Australian wheat varieties of the mixed 2004 and 2005 products of each variety separately. We utilized the Grain & Flour Analyzer Infratec 1241; the results are presented in **Table 6a-6e**. We observed the following:

Crude Protein: The % crude protein in the flour varied according to the wheat variety, yield, and % flour extraction from 70 to 80 to 100%. The % crude protein was increased as % flour extraction was increased. The average percentage of crude protein on the flour of 70% extraction was 11.96%, and it increased slightly to 12.00% on the 80% flour; and on 100% extraction, it reached 13.85%, see **Table 6a**. At all extractions, the % crude protein ranged from 11.33 to 14.69%, which was acceptable for bread baking, and the average % crude protein on Kennedy was the highest with 13.34%, followed by Drysdale then Lang then Giles with 12.61, 12.36, 12.11% respectively. Increased % crude protein in the flour is desired as it leads to increased dough strength.

% Moisture Content: To facilitate grains milling at the silos mill, the grains' moisture content was raised to around 14%. The average % moisture content of the flour samples ranged from 10.41 to 11.59%, which is acceptable for safe storage of the flour before processing by the bakeries, see **Table 6b.**

3- % Ash: This represents the percentage of mineral elements in the flour. It is an indicator of flour extraction after milling. There was an increase of %ash with increased % flour extraction from 70% to 80 to 100%. All of the varieties shown a similar high %ash increase at 100% and slightly increase at 70 to 80% extraction.

The average %ash on the varieties at 70% flour extraction was 0.60%; on 80% it was 0.67% and on 100% flour extraction it reached 1.25%. There was a slight difference of % ash between the varieties at each flour extraction, see **Table 6c**. Low %ash is desired in the wheat flour as the flour color appears whiter, while high % ash in the flour appears with less white color.

- % Water Absorption: There was a slight increase in the %water absorption with increased flour extraction from 70 to 80 to 100%. Drysdale has shown the highest %water absorption increase at all extractions, and at 100% extraction, it was 66.32%, followed by Kennedy then Lang Giles with 64.75, 64.24, 62.74% respectively, see **Table 6d**. The bakeries desire increased relative % water absorption of the flour as it produces more bread quantity.

5- % Wet Gluten: The % wet gluten was slightly increased as % flour extraction was increased from 70 to 80% to 100%. At all extractions, the % wet gluten ranged from 25.8 to 30.05%, which was reasonable, and at 100% extraction, Kennedy and Drysdale had the highest %wet gluten with around 30%, followed by Giles then Lang with 29.43, 29.2% respectively, see **Table 6e**. High values of % wet gluten are desired as it is an indication of good flour quality.

Table 6a. % Crude protein at different flour extractions on the samples of four Australian bread wheat varieties.

Type of Flour Sample	% Crude Protein in the Flour of Wheat Varieties				Mean	Acceptable level
	Giles	Kennedy	Drysdale	Lang		
70% Extraction	11.33	12.75	11.8	11.95	11.96	> 12%
80% Extraction	11.60	12.57	12.08	11.55	12.00	
100% Extraction	13.19	14.69	13.94	13.58	13.85	
Mean	12.11	13.34	12.61	12.36		

Table 6b. The % moisture content on the flour samples at different extractions of the Australian wheat varieties.

Type of Flour Sample	% Moisture Content in the Flour of Wheat Varieties				Mean	Acceptable level
	Giles	Kennedy	Drysdale	Lang		
70% Extraction	11.34	11.43	11.42	11.29	11.37	12 – 14%
80% Extraction	11.54	11.52	11.55	11.17	11.45	
100% Extraction	11.40	10.41	11.59	11.04	11.11	

Table 6c. The % Ash on the flour samples at different extractions of the Australian wheat varieties.

Type of Flour Sample	% Ash in the Flour of Wheat Varieties				Mean	Acceptable level
	Giles	Kennedy	Drysdale	Lang		
70% Extraction	0.57	0.64	0.61	0.59	0.60	< 0.6%
80% Extraction	0.65	0.69	0.68	0.65	0.67	< 0.7%
100% Extraction	1.24	1.27	1.27	1.2	1.27	< 1.3%
Mean	0.82	0.87	0.85	0.81		

Table 6d. % Water absorption on the flour samples at different extractions of the Australian wheat varieties.

Type of Flour Sample	% Water Absorption in the Flour of Wheat Varieties				Mean	Acceptable level
	Giles	Kennedy	Drysdale	Lang		
70% Extraction	60.15	61.95	63.99	62.6	62.17	60 – 66%
80% Extraction	60.51	62.33	64.16	62.62	62.41	
100% Extraction	62.74	64.75	66.32	64.24	64.51	

Table 6e. % Wet Gluten on the flour samples at different extractions of the Australian wheat varieties.

Type of Flour Sample	% Wet Gluten in the Flour of Wheat Varieties				Mean	Acceptable level
	Giles	Kennedy	Drysdale	Lang		
70% Extraction	25.8	28.43	27.97	27.71	27.48	Higher values are desired
80% Extraction	26.53	29	28.1	27.48	27.78	
100% Extraction	29.43	30.05	30.02	29.2	29.68	

F- Flour/Dough Quality [16], [18]:

The results of the flour/dough samples analysis are presented in **Table 7**; we observed the following:

Falling Number: The falling number is an indicator of alpha-amylase enzyme activity, which causes starch degradation (hydrolysis). The falling number was slightly increased as % flour extraction was increased from 70 to 80% on all varieties except Drysdale. At flour extraction 70% Drysdale was with the highest falling number, which reached 707 seconds, followed by Kennedy with a falling time of 657 seconds, then Giles with 617 seconds, then Lang with 432.5 seconds see **Figure 5**. At flour extraction, 80% Kennedy was with the highest falling number, which reached 726.5 seconds, followed by Drysdale with a falling number of 691 seconds, then Giles with 656.5 seconds, then Lang with 538 seconds. As per the falling number results, all of the varieties were Suitable for making Arabic bread.

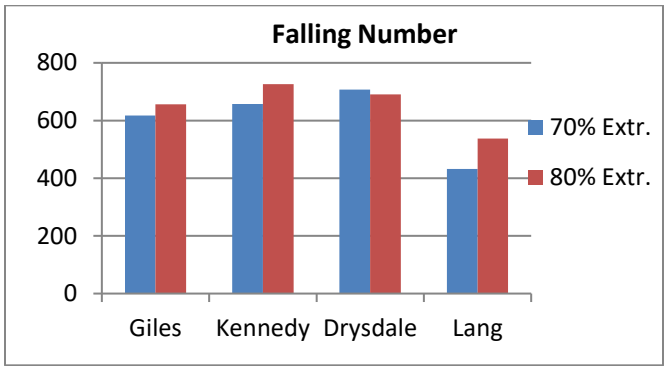

Figure 5. The falling number on the flour samples' dough at two flour extractions of the Australian wheat varieties.

Table 7. Laboratory analysis results on the flour/dough of the mixed 2004 and 2005 product samples of four Australian bread wheat varieties, see appendix pictures A to H.

Flour Extraction	Type of Analysis	Bread Wheat Varieties				Acceptable Level
		Giles	Kennedy	Drysdale	Lang	
70% Flour Extraction	Falling Number (seconds)	617	657	707	432	300 – 600
	% Water Absorption at Peak Consistency (500 FU)	61.6	63.3	65	63.5	60 – 66
	Development Time (minutes)	3.9	4.5	3.7	3.5	4 – 7
	Stability at Peak Consistency ((minutes)	4.9	5.9	4.8	3.3	Higher values are desired
	Degree of Softening 10 minutes after begin (FU)	50	42	56	67	Lower values are desired
	Degree of Softening 12 minutes after begin (FU)	75	67	81.5	88	Lower values are desired
	Farinograph quality number	67	79	67.5	51	Higher values are desired
80% Flour Extraction	Falling Number (seconds)	656.5	726	691	538	300 – 600
	% Water Absorption at Peak Consistency (500 FU)	61.9	65	65.1	63.3	60 – 66
	Development Time (minutes)	3.3	4.8	33.8	4.0	4 – 7
	Stability at Peak Consistency (minutes)	3.8	4.4	4.25	3.9	Higher values are desired
	Degree of Softening 10 minutes after begin (FU)	57	41	50.5	52	Lower values are desired
	Degree of Softening 12 minutes after begin (FU)	77	68	75.5	74	Lower values are desired
	Farinograph quality number	60	76	65	66	Higher values are desired

FU: Farinograph units or Brabender units

F1- Farinograph Tests [20]: The Farinograph is a tool used to assess flour doughs' baking qualities and performance. It measures and records the dough's strength, elasticity, and consistency mixed from flour and water. In other words, the Farinograph is used to assess the rheological properties of the wheat flour when it is mixed with water to form the dough. This is a complex process and can be identified into three processes: water absorption, dough development, and dough break down. The Farinograph measures the energy required to mix the dough as it progresses through these stages of development. From these pieces of information, the dough's relative quality characteristics can be assessed [16].
Diagrammatic illustration on Farinograph parameters tests: dough development time, stability, and the dough is softening are shown in **Figure 6**. We observed the following:

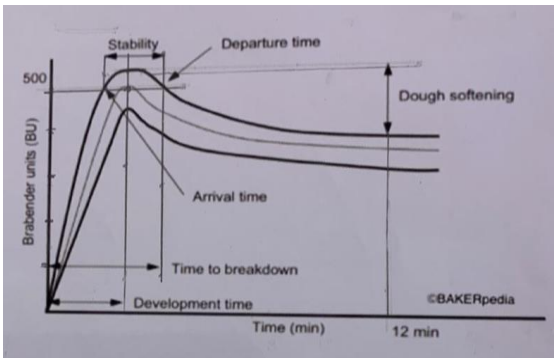

Figure 6. Diagrammatic illustration of the Farinograph parameters on the flour dough made from flour and water mixture (bakerpedia.com) [21].

1- %Water absorption: The amount of water required to develop dough that centers the Farinograph trace on a 500-FU line. The relative %water absorption was increased slightly as % flour extraction was increased from 70 to 80% except on Lang, see **Figure 7**. At flour extraction 70%, Drysdale had the highest relative %water absorption, which reached 65%, followed by Lang, then Kennedy, then Giles with 63.5, 63.3, and 61.6%, respectively.

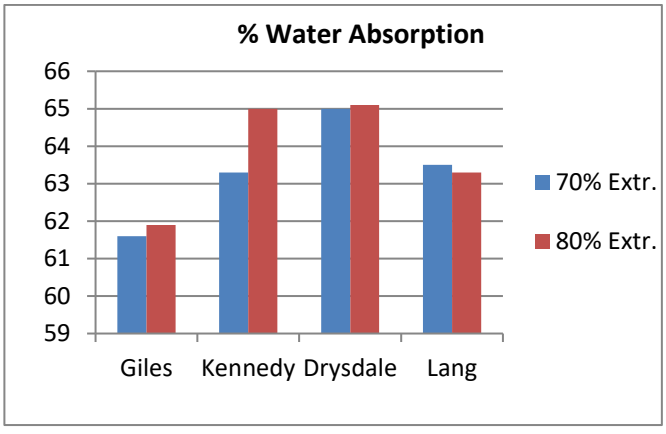

Figure 7. The %Water absorption of the flour samples at two flour extractions of the Australian wheat varieties.

At flour extraction 80%, Kennedy has shown a slight increase in water absorption with 65%, but other varieties have shown a slight change. As per the %water absorption results, all of the varieties were suitable for making Arabic bread except Giles at 100% extraction.

2- Development Time: It is the period needed to prepare the dough to reach peak consistency. Stronger flours with higher protein content have a longer development time than weaker flours of the same extraction%, and the acceptable level is 4 – 7 minutes. The development time was increased as % flour extraction was increased from 70 to 80% except on Giles it was decreased. At flour extraction 70%, Kennedy was with the highest development time, which reached 4.5 minutes, followed by Giles then Drysdale and Lang with 3.9, 3.7, and 3.5 minutes respectively. At 80% extraction, Kennedy and Lang were with the highest development time, which reached 4.8 minutes, followed by Drysdale, then Giles with 3.75, 3.3 minutes, see **Figure 8**. These results indicate that Kennedy was suitable for the baking industry at 70 and 80 % extraction, while Lang was suitable for the baking industry at 80%.

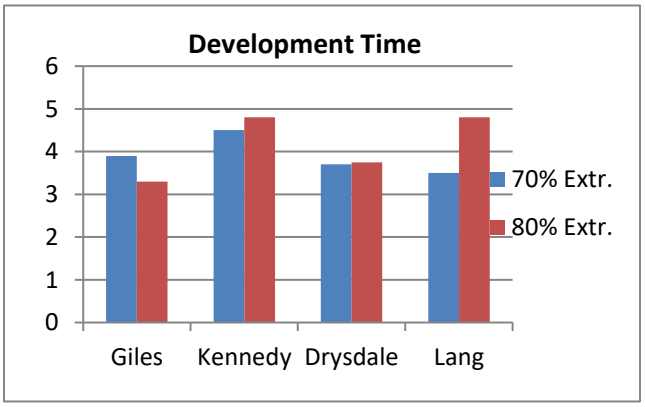

Figure 8. The development time on the flour samples' dough at two flour extractions of the Australian wheat varieties.

3- Stability at Peak Consistency: It is the measurement for the time difference in minutes between when the dough reaches peak stability and the point when it starts to become weak (resistance to overmixing). Stronger flours are usually more stable than weaker ones from the same wheat class; higher values are desired. The stability of the dough of the flour samples at different flour extractions is presented in **Figure 9**. The dough stability was decreased as flour extraction was increased from 70 to 80% except on Lang. At flour extraction 70%, Kennedy was with the highest stability time, which reached 5.9 minutes, followed by Giles then Drysdale, then Lang with 4.9, 4.8, and 3.3 minutes. At flour 80% extraction, Kennedy was with the highest stability time, which reached 4.4 minutes, followed by Drysdale, then Giles, then Lang with stability time 4.3, 3.9, 3.8 minutes, respectively. These results indicate that the varieties

Kennedy, Drysdale, and Giles were with good stability at 70% flour extraction, so they are suitable for the baking industry at this Extraction. In comparison, at 80% of the varieties, Kennedy and Drysdale were suitable for the baking industry.

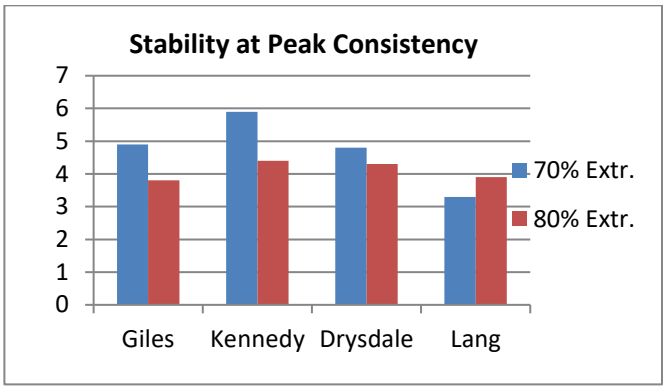

Figure 9. Stability at Peak Consistency in the dough of the flour samples at two flour extractions.

4- Degree of Dough Softening after beginning (FU): It is measured 10 minutes after the start of the Farinograph and after 12 minutes when the dough is reaching peak consistency, and high values after 12 minutes are desired as they indicate stronger flour dough. Measurements after 12 minutes for the dough softening of the flour samples at different flour extractions are presented in **Figure 10.** At 70% flour extraction, the degree of dough softening reached 88 FU on Lang, and this was the highest, followed by Drysdale with 81.5 FU, then Giles and Kennedy with 75, 67 FU, respectively. At 80% flour extraction, Giles reached 77 FU, followed by Drysdale, then Lang, then Kennedy with 75.5, 74, 68 FU, respectively. Results are shown as % flour extraction was increased; the degree of dough softening was decreased on Lang and Drysdale, while on Giles and Kennedy, it was slightly increased.

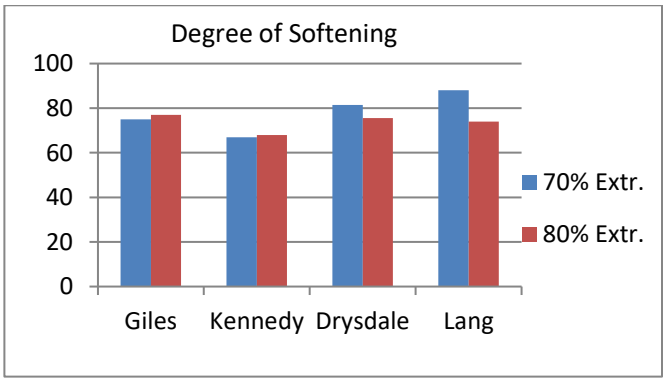

Figure 10. Degree of softening at peak consistency in the dough of the flour samples at two flour extractions.

5- Farinograph Quality Number (FU): This is a measure of the dough quality; an increased number indicates better dough quality. The Farinograph quality number is shown in **Table 8a** and **Figure 11**. Farinograph quality number for the dough at 70% flour extraction reached 79 FU on Kennedy, and this was the highest followed by Drysdale with 67.5 FU, then Giles and Lang with 67, 51 FU respectively.

At 80% flour extraction, Kennedy reached 76 FU, followed by Lang, then Drysdale, then Giles with 66, 65, 60 FU, respectively. Flour/dough with higher values is desired for baking than lower values. These results indicate Kennedy was with the best flour/dough quality number.

Table 8a. The Farinograph quality number on the dough of flour samples at different flour extractions.

Type of Flour Sample	Farinograph Quality Number (FU)				Mean
	Giles	Kennedy	Drysdale	Lang	
70% Extr.	67	79	67.5	51	66.13
80% Extr.	60	76	65	66	66.75

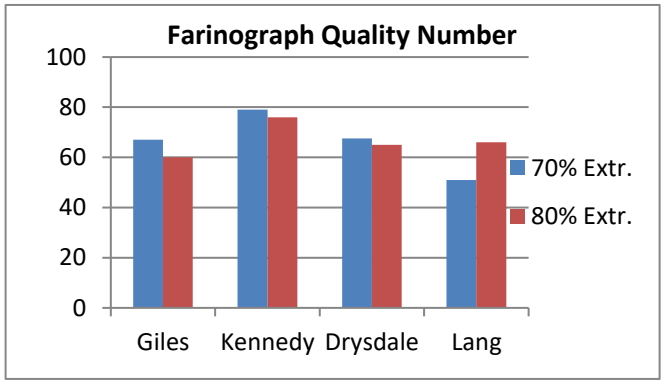

Figure 11. The Farinograph quality number on the dough of flour samples at two flour extractions.

Summary for the evaluations on the quality of the four Australian bread wheat varieties' flour and dough are presented in **Table 9.**

G- Baking Quality:

The results of baking experiments conducted at two bakeries in Tabuk city were as follows:

Bakery A: The results on the 80% flour extraction of Kennedy and Giles varieties shown the loaves of the flat Arabic Bread were swelling into two layers, the outer surface color was white, loaf texture was consistent thin with fresh bread aroma, the taste was good, fluffy and easy for chewing. The bread taste was better than the bread made from the local wheat variety Yecora Rojo. Also, we observed another type of bread from this experiment: dry Qarshali bread from the extract 70% for tea snacks: it was of good quality. Small Sameet Bread with sesame seeds: it was tender and delicious, and the pulp was spongy. Bread for a hamburger (Hearth bread): the pulp was swollen and spongy with pores, and the taste was very good.

Bakery B: The 80% flour extraction of Lang and Drysdale shown the toasted bread (white pan bread) was with brownish's outer color, and the inner color was bright white. The taste was excellent and similar to the cake taste as it melts in the mouth and outperforms the taste of Yecora Rojo toast. Results on Samuli shown the bread was with brownish skin color and did not peel off when it was cold. The pulp was white with a spongy appearance and excellent taste. Results on flat Arabic bread shown the inner color of this bread was white, yellow and the taste was good, and the loaf is thicker than in Bakery A.

Summary for the evaluations on the quality of the four Australian bread wheat varieties' flour and dough are presented in the following **Table 9.**

Flour Extraction	Comparison Item	Bread Wheat Varieties			
		Giles	Kennedy	Drysdale	Lang
70% Flour Extraction	% Ash	as required	as required	as required	as required
	% Protein	medium	high	medium	medium
	% Moisture Content	as required	as required	as required	as required
	Falling Number	very high	very high	very high	medium
	% Water Absorption	good	very good	very good	very high
	Development Time	fast	medium	fast	fast
	Stability at Peak Consistency	very good	very good	very good	good
	Degree of Dough Softening	slow	slow	medium	medium
	Farinograph Quality Number	good	excellent	good	low
80% Flour Extraction	% Ash	as required	as required	as required	as required
	% Protein	medium	high	high	medium
	% Moisture Content	as required	as required	as required	as required
	Falling Number	very high	very high	very high	high
	% Water Absorption	good	very good	very good	very high
	Development Time	Fast	medium	Fast	medium
	Stability at Peak Consistency	good	very high	good	very high
	Degree of Dough Softening	slow	slow	slow	slow
	Farinograph Quality Number	low	excellent	good	good

IV. CONCLUSION

1- Field trials results in the three cropping seasons 2004 – 2006 show that the Australian wheat variety Lang was the highest producing variety with an average of 8.21 M.T./Ha followed by Giles then Drysdale then Kennedy with an average of 7.84, 7.48, 7.16 M.T./Ha respectively. During this study, we observed that each variety's productivity reached above 8 M.T. /Ha when they were grown under optimum growing conditions, as shown by the Kennedy variety's productivity in 2006, which reached 8.04 M.T. /Ha contrary to low productivity in 2004 and 2005. So, the Australian varieties' productivity under the Centre pivot irrigation system matched the productivity of Yecora Rojo with a general average of 8.07 M.T. /Ha.

2- Under the growing conditions and crop maintenance programs at TADCO, no serious wheat disease such as rusts, smuts, Septoria, etc. was observed on the Australian wheat varieties during the trials period. We observed a serious lodging problem on Giles in the third season, which affected harvesting this variety apparently due to the effect of high nitrogen fertilizer application, which leads to lodging under the effect of the strong wind blowing.

3- Results in the 2004 season show that the grains of Yecora Rojo variety were higher than the Australian varieties grains in terms of %Protein Content, %Wet Gluten and Zeleny value %Starch, Test Weight as kg/hl on the Australian varieties was higher than on Yecora Rojo. The average % crude protein of the Australian wheat varieties over the three seasons was 12.39%, while on Yecora Rojo, it was 14.10%, which was higher by 1.71%. Comparison between the Australian wheat varieties shown Kennedy variety was with the highest %crude protein in 2004 and 2005 seasons, which reached 13.45, 14.52%, respectively. As productivity was increased in 2005, the % crude protein, %wet gluten, and Zeleny value was decreased on the other three varieties and Yecora Rojo. In the 2006 season, Zeleny's value on Kennedy variety was higher than other Australian varieties and Yecora Rojo variety. Increased % crude protein, % wet gluten in the grains of the varieties indicated high grain quality. It increased the Zeleny value was an indication of more dough strength desired in good wheat flour.

4- The particle size index (psi) test shown the grains of Drysdale were the hardest with psi 9.5, followed by Yocora Rogo with 9.6, then Kennedy with 10.1, then Lang 11.02, and finally Giles grains was the lowest with psi 13.3. According to these results, the wheat varieties kernels were classified as hard except Giles kernels.

Table 10. The falling number of Australian wheat varieties at different flour extraction

%Flour Extraction	Falling Time (Seconds)				
	Giles	Kennedy	Drysdale	Lang	Yecora Rojo
100% Dubai Mill	483	551	533	479	586
80% Tabuk Silos	656.5	726.5	691	438	- -
70% Tabuk Silos	617	657	707	432	- -

5- Results on the falling number (seconds) at 100% flour extraction shown that Yecora Rojo was with the highest falling number of 586 seconds, followed by Kennedy with 551 seconds, then Drysdale with 533 seconds, then Giles with 483 seconds, and finally Lang with a falling time of 479 seconds as shown in the following **Table 10**.

At flour extraction 80%, Kennedy was with the highest falling number, which reached 726.5 seconds, followed by Drysdale with a falling time of 691 seconds, then Giles with 656.5 seconds, then Lang with 538 seconds. At flour extraction 70%, Drysdale was with the highest falling number, which reached 707 seconds, followed by Kennedy with a falling time of 657 seconds, then Giles with 617 seconds, then Lang with 432.5 seconds. As per the falling number results, all of the varieties were suitable for making Arabic bread as the acceptable level is 300 – 600 seconds. A low falling number is related to the alpha-amylase enzyme [16], [17] in the flour. This enzyme's increased activity causes starch degradation (hydrolysis), which affects the quality of the flour and the products made from it such as the dough's viscosity and the difficulty of making the sliced bread. The lower the enzyme activity leads to longer falling numbers, indicating better grains and flour quality.

6- Observations on the flour and dough of the Australian varieties [16], [18] shown the % crude protein on Kennedy flour at 70, and 80% extraction was above 12%, and this was excellent for bread baking, and similar results were observed at 70% extraction on Drysdale. The % crude protein on the other two varieties ranged between 11.33 – 11.95%, which was acceptable for bread baking. Increased % crude protein in the flour is desired as it leads to increased dough strength. The % ash in the wheat flour is an indicator of the flour extraction, and as %flour extraction was increased, the %ash was increased. The results showed the % ash on the Australian flour extraction of 70 and 80% was 0.60, 0.67%, respectively, and relatively low. Low %ash is desired in the wheat flour as the flour color appears whiter, while high % ash in the flour appears with less white color. The Australian wheat varieties' flour color was brilliant white at 70 and 80% extractions except for Drysdale at 80%. It was less white. These results indicate the Australian varieties belong to the hard white Wheat. The relative %water absorption on all of the varieties ranged from 60.15 - 64.16, which was acceptable for baking processing. The bakeries desire increased relative %water absorption of the flour as it produces more bread quantity. The flour/dough mix of Kennedy, Drysdale, and Giles was with strong dough, and for Lang, it was with medium strength; the mixing time for the varieties dough was relatively short with good stability time. These were acceptable for bread baking. The 80% flour extraction of all Australian wheat varieties was suitable for bread baking, which is economical for the bakeries processing.

7- It was observed that all Australian wheat varieties were produced in good flat Arabic bread at 80% flour extraction. Generally, they were superior in quality compared to the Bread of Yecora Rojo variety. It was also noted that fresh Bread of Kennedy and Lang varieties were with excellent taste, white color with a nice smell, and exceeded the other Australian varieties. Kennedy of 70% flour extraction shown excellent bread products of same, Samuli and qurshali products. Lang of 80% flour extraction shown excellent toast bread (white pan bread) melts in the mouth in addition to Arabic flatbread and Samuli bread and outperforms the toast of Yecora Rojo bread.

8- Sum up on the Australian wheat varieties characters and quality [5], [8], [10] shown:

***Kennedy*:** Hard white Wheat, high dough strength with long mixing time, excellent baking quality, no serious disease incidence, medium yield.

***Lang*:** Hard white Wheat, good dough strength with long mixing time, very good baking quality, no serious disease incidence, high yield.

***Drysdale*:** Hard white Wheat, high dough strength with long mixing time, medium baking quality, medium yield, drought-resistant

***Giles*:** Hard white Wheat, high dough strength with poor extensibility, average baking quality, good yield, high lodging incidence.

9- Field, Laboratory, Silos, and Bakeries tests shown three bread wheat varieties Kennedy, Lang, and Drysdale were found suitable for wheat production and food processing. Giles need further blending tests with the chosen varieties for food processing.

10- The utilization of the Infratec 1241 grain & flour analyzer in this research work was found easy to operate, fast, accurate, and useful for analyzing different samples of grains and flour [11]. It was a useful tool in the research studies towards screening new varieties of bread wheat in different geographical areas.

11- Due to economic reasons, the negotiation between

TADCO and the Australian wheat seeds companies did not materialize into a final agreement to localize the Australian wheat varieties' cultivation in the Tabuk area. So the research work was directed towards investigating new varieties from the CIMMYT under the name 3rd Elite bread wheat (3rdEBW) in 2008.

Appendix pictures A – H: Silo Lab Flour/ Dough apparatus & mill factory

A. Grain Sampler from Trucks

B. Grain Samples Cleaner

C. Grains Milling Machine

D. Falling Number Apparatus

E. Farinograph Apparatus

F. Flour Dough Mixer

G. Milling Factory

H. Stock of 70% and 80% Flour Extractions

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