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The Color of Scoured and Carded Wools: A Comparison of U.S., Australian and New Zealand Wools

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Summary

Fifty greasy core samples of wool fibers representing various regions of the United States were obtained from Yocom-McColl Testing Laboratories. In addition 50 greasy core sample of New Zealand wool (Société Générale de Surveillance [SGS]) and 10 greasy core samples Australian Wool Testing Authority (AWTA) were obtained. After scouring, average fiber diameter and clean color were determined. After measurement of clean color, the samples were carded to evaluate its effect on the measured color of the wool. Color measurements of the scoured and the scoured and carded wools clearly indicated that there were differences between the yellowness of the samples. Wools from each country were grouped according to fiber diameter into four groups; <20 µm , 20 – 22.9 µm, 23 – 25.9 µm, and ≥26 µm, and color was evaluated for each group. The results indicated that in most cases the mean color among samples was not significantly different which was expected. However, U.S. wools had a much wider range of yellowness indices compared to those from Australian and New Zealand.

Key words: Wool, Clean Color, Yellowness

Introduction

The color of wool is an important characteristic. It provides for example, a limit to the dyeing potential of that wool. Clean-color specification is becoming increasingly more important for wool marketing, especially for both high quality wool and lower types, such as pieces and bellies (Australian Wool Corporation, 1987). Greasy wool color is determined not only by the inherent color of the wool, but also by the grease, suint, dirt and vegetable matter the wool contains. These extraneous materials are removed in processing by scouring and carding. Therefore, these impurities do not affect the color of the final product. Thus, before a relevant color measurement can be made, greasy wool must be processed to a state of cleanliness.

The technical demands and limitations of manufacturing worsted and woolen yarns, weaving and knitting fabrics require individual items in the broad spectrum of wool textile products to be composed of specific grades or classes of wool or blends thereof. Since between and within fleece variation of diameter, color, length, strength and degree of cleanliness is often large, normal quality control requires fleeces to be graded and sorted prior to scouring. Traditionally, this function has been performed at the textile mills or by companies that specialize in providing specific grades of raw materials to the textile industry. An opportunity has and still does exist for ranchers to skirt and grade wool either at shearing or pay a marketing organization to do the job for them. Theoretically, when it is no longer necessary for a textile mill to perform these tasks, labor savings can be passed back to the grower on return for prepared wools. Such efforts to increase the value of raw wool have been practiced for years by individual ranchers and at some warehouses and co-ops.

To be able to characterize wools from the United States is a primary requirement in developing marketing strategies. Characterization includes determination of both greasy and clean wool characteristics. These fiber specifications are directly related to the potential spinning performance. Characteristics to be measured are those which the industry uses as a guideline for predicting processing performance of wool. They also allow for the prediction of how different wools will perform when blended together. Color is becoming an increasingly important parameter for processors. The primary purpose of this project was to evaluate the color of U.S. wools as compared to wools obtained from Australia and New Zealand.

Materials and Methods

Fiber Samples

Fifty greasy core samples of U.S. wools representing various regions of the United States were obtained from Yocom-McColl Testing Laboratories Inc, Denver, Colo. In addition, 50 greasy core samples of New Zealand wools were randomly obtained from commercial lots tested in the laboratory of SGS New Zealand and 18 randomly selected greasy core samples of Australian wools tested in the AWTA Sydney laboratory were obtained. All core samples were processed by Yocom-McColl according to American Society of Testing and Materials (ASTM) test method ASTM D584-96 (ASTM, 1998) and average fiber diameters were determined. The laboratory scouring process involves a mild alkali scour followed by rinsing and drying at 105°C.

Determination of Fiber Diameter

Fiber diameter of the scoured core residue was measured using the Sirolan-Laserscan (AWTA, Sydney) (IWTO-12, 1993). A sub-sample of the core residue was minicored to obtain 2mm long fiber snippets that were subsequently utilized to determine average fiber diameter, standard deviation and coefficient of variation of the sample.

Determination of Yellowness Indices

Yellowness indices were determined using a Spectrogard Color Control System (Pacific Scientific, Silver Spring, Md.). ASTM E313-96 (ASTM, 1998b) was utilized to calculate yellowness indices (YIE). As yellowness increases YIE values increase. In addition, the Y/Y-Z value of yellowness was also calculated. The Y value indicates the lightness of the wool sample (lightness generally ranges between 50 to 70) with the higher values denoting lighter wools. Y-Z denotes the yellowness of the sample and generally ranges from -2 to 12. The greater the yellowness the higher the Y-Z value (Cottle et al., 1992). Eight measurements per sample were taken for both scoured and carded wool samples.

Statistical Analysis

Statistical analyses were conducted using SAS (SAS Institute, 1995). T-tests were used to determine differences in color between paired scoured- and carded-wool samples and to determine differences between wools from different countries and different micron groups.

Results and Discussion

Average fiber diameters and yellowness indices for U.S. wool samples are shown in Table 1. There is a wide range of fiber diameters with samples ranging from 18.6 µm to 32.9 µm. Yellowness indices of 50 pairs of scoured and carded wools (U.S.) clearly indicated that carding improved the color of the wool. In the majority of cases (36 samples) carding significantly improved (decreased) the YIE value. A lower value for YIE indicates a sample that is less yellow or a sample that is more white. While not being significantly different, nine additional samples had lower carded YIE values compared to the scoured value. When evaluating color based on Y-Z values, 31 samples showed significant improvement after carding while a further 12 showed improved values, though not significant. As with the case of YIE, a lower Y-Z value indicates whiter wool. These results were as expected, as carding is a further cleaning process and thus would be expected to remove further dark-colored, extraneous material, which can impact the overall clean color of wool. In fact there is an accumulative effect with scouring and carding, which can be taken even further with subsequent combing, dyeing and finishing in changing the color of wool.

The yellowness of the U.S. scoured wools ranged from a high of 33.63 to a low of 20.69 (YIE) and a high of 20.77 to a low of 4.17 (Y-Z), while with the carded wools the yellowness ranged from a high of 30.77 to a low of 17.87 (YIE) and a high of 11.49 to a low of 2.47 (Y-Z). Thus there is a wide variation when looking at individual wool samples. However, in terms of yellowness, it would appear that even after carding the wools continue to be quite yellow. Aus-

Table 1. Yellowness indices of scoured and carded U.S. wool samples.

Sample Number	Average Fiber Diameter (µm)	YIE[1]		Y - Z[2]	
		Scoured	Carded	Scoured	Carded
87025	24.3	23.79	24.26	6.31	7.08
87081	22.1	24.79	21.28***	6.56	4.92**
87083	22.3	26.60	20.17***	17.57	3.96***
87150	30.6	33.53	30.71*	10.17	10.47
87156	21.8	24.36	17.87***	16.89	2.47***
87163	27.0	29.79	27.40**	9.36	8.61
87167	20.8	25.75	24.47**	7.74	7.15*
87173	22.2	22.96	23.75	5.66	6.50
87221	30.4	28.18	24.10***	7.51	6.14**
87250	22.1	26.61	25.10**	6.96	6.99
87252	22.1	28.83	25.82**	10.21	8.19*
87253	21.8	32.40	27.34***	13.41	9.47
87254	25.4	33.63	30.77*	20.77	11.49***
87259	23.1	22.72	19.98*	5.68	3.73*
87260	20.9	25.53	21.11***	7.51	4.64
87265	20.0	28.67	24.09***	19.17	7.02***
87283	21.9	27.03	23.98***	17.75	10.46
87291	22.9	20.87	19.46	4.17	3.23
87295	22.3	22.39	20.97	5.55	4.75
87306	18.6	26.83	23.69***	7.82	6.76**
87307	20.7	26.07	23.16**	7.58	6.25*
87323	18.9	26.41	22.52***	7.95	5.92**
87325	19.8	29.33	24.19***	18.91	7.17***
87327	21.0	27.05	25.32	8.69	7.54
87328	22.0	27.28	21.93***	16.84	4.96***
87343	20.7	27.06	21.00***	18.60	4.59***
87360	20.3	27.58	22.97***	18.17	6.19***
87370	20.8	23.46	19.09***	16.52	3.13***
87415	21.8	20.69	19.54	4.26	3.42
87425	23.3	23.41	18.45***	15.76	2.57***
87428	24.1	21.14	21.37	4.34	6.65
87432	22.1	26.03	21.84***	16.84	4.96***
87440	22.3	21.89	19.90**	5.01	3.71*
87442	22.5	26.61	20.93***	16.65	4.20***
87443	25.4	25.59	21.46***	16.09	4.74***
87449	23.6	25.45	20.54***	16.62	4.05***
87468	32.9	28.34	23.50***	8.58	6.17***
87469	19.5	24.32	23.26	6.68	6.16
87475	19.7	25.96	23.95**	6.83	6.51
87484	21.0	24.84	20.06***	16.65	3.80***
87488	22.1	22.23	21.16	5.24	4.53
87492	25.9	25.42	21.22***	6.44	4.29***
87494	19.3	25.05	20.38***	6.59	3.99***
87499	29.2	29.56	26.89	18.37	8.35***
87500	20.9	28.04	23.66***	19.02	6.46***
87504	18.9	25.72	24.29	6.95	6.79
87511	23.5	25.23	21.91***	16.16	5.03***
87512	21.4	22.83	23.23	5.31	6.08*
87519	23.8	23.40	23.32	5.84	6.35
87520	21.3	20.76	21.26	4.18	4.64

* $p<0.05$, ** $p<0.01$, *** $p<0.001$
[1] Yellowness Index (YIE) – as yellowness increases, YIE increases
[2] Yellowness Index (Y-Z) – as yellowness increases, Y-Z increases

tralian wools by comparison generally have Y-Z values ranging from 1 to 4 (Cottle and Zhao, 1995), although in this study we found Australian wools to range from 2.72 to 10.05. Of the 50 U.S. samples evaluated only ten had Y-Z values of less than 4 even after carding. Only three of the 18 Australian samples had Y-Z values of less than 4 after carding. The difference in yellowness values found for Australian wools in this study compared to previously reported studies could be explained by the fact that these wools were given an alkali scour, which typically results in an increased yellowness. Australian wools are usually given a neutral detergent scour, which generally results in a whiter (less yellow) fiber. It is important to note however, that all wools in this study were processed in the same manner. An alkali scour was used in this study as per ASTM D584-96 procedures (ASTM, 1998a).

Average fiber diameters and yellowness indices for New Zealand wool samples are shown in Table 2. Fiber diameters ranged from 17.5 µm to 38.6 µm. Yellowness indices of 50 pairs of scoured and carded wools clearly indicated that carding also improved the color of these samples. In half of the samples (25 cases) carding significantly improved (decreased) the YIE value while in an additional 20 cases, though not significant, the samples had lower carded YIE values compared to the scoured value. When evaluating color based on Y-Z values, 15 samples showed significant improvement after carding while a further 25, though not significant, showed improved values. As with the case of YIE, a lower Y-Z value indicates a whiter wool.

The yellowness of these wools when scoured ranged from a high of 40.02 to a low of 24.20 (YIE) and a high of 13.96 to a low of 6.25 (Y-Z), while with the carded wools the yellowness ranged from a high of 38.19 to a low of 22.14 (YIE) and a high of 15.69 to a low of 5.17 (Y-Z).

Average fiber diameters and yellowness indices for Australian wool samples are shown in Table 3. Fiber diameters ranged from 19.2 µm to 36.3 µm. Yellowness indices of 18 pairs of scoured and carded wools clearly indicates that carding also improved the color of these samples. In six samples carding significantly improved (decreased) the YIE value while in the other 12 cases, though not

Table 2. Yellowness indices of scoured and carded NZ wools.

Sample Number	Average Fiber Diameter (µm)	YIE[1]		Y – Z[2]	
		Scoured	Carded	Scoured	Carded
00001	31.4	26.89	25.61	8.59	7.61
00002	34.9	31.61	29.61*	10.69	9.58*
00003	24.1	28.86	27.64	9.84	8.98
00004	26.4	34.99	32.93*	11.31	10.98
00005	35.9	33.15	31.60**	11.75	11.55
00006	26.0	31.44	29.65**	11.15	10.32*
00007	32.6	30.78	28.55**	10.55	9.39*
00008	19.6	29.41	28.66	9.87	10.07
00009	34.6	34.09	30.75*	12.59	10.90
00010	30.9	27.51	25.76*	8.50	7.39*
00011	33.3	39.05	37.68	13.96	14.07
00012	35.5	30.97	28.73*	10.22	9.47
00013	33.3	27.76	26.24**	8.46	8.15
00014	22.3	25.27	24.65	7.29	7.22
00015	18.2	25.84	25.27	7.16	7.07
00016	26.3	26.68	24.85	8.10	6.90
00017	19.1	25.48	22.62**	7.65	5.57**
00018	31.1	27.40	25.06***	8.36	7.05**
00019	35.7	32.21	30.30*	11.39	10.41
00020	19.1	26.53	25.21	8.11	7.26
00021	36.9	33.54	31.98*	12.55	11.59
00022	28.5	28.25	28.42	9.00	9.74
00023	18.4	25.09	22.14**	7.18	5.41**
00024	18.8	24.19	23.10	6.53	6.00
00025	21.7	28.07	26.29	9.27	8.36
00026	36.6	32.62	28.50***	13.11	9.21*
00027	20.7	27.76	27.80	7.49	8.15
00028	20.7	26.90	27.03	7.47	8.26
00029	30.2	29.96	28.36**	10.47	9.19**
00030	31.2	32.69	29.27**	11.52	9.83*
00031	21.4	27.63	26.32	8.35	8.21
00032	26.2	30.70	28.59**	10.02	9.59
00033	24.6	28.58	27.28	10.02	9.26
00034	22.0	27.94	28.43	8.83	9.29
00035	26.2	25.03	23.69*	7.05	7.25
00036	21.1	24.20	22.22**	6.25	5.17
00037	20.8	33.35	32.42	11.82	11.88
00038	18.9	26.76	25.70	8.22	7.87
00039	32.9	29.85	28.07*	10.14	9.37
00040	25.8	26.06	23.07**	8.18	6.12*
00041	22.4	30.06	28.40	10.34	9.88
00042	24.5	31.12	29.52	10.27	10.03
00043	37.7	35.54	34.54	13.07	13.06
00044	38.6	34.56	31.58***	12.67	10.86***
00045	18.9	29.73	28.86	9.92	9.61
00046	19.5	28.44	26.56	9.55	12.50
00047	28.6	35.80	38.19	13.36	15.69*
00048	28.7	40.52	32.09	13.62	11.96
00049	25.6	29.42	25.74*	10.12	7.83*
00050	17.5	27.59	23.68**	8.96	6.41**

* $p<0.05$ ** $p<0.01$ *** $p<0.001$
[1] Yellowness Index (YIE) – as yellowness increases, YIE increases
[2] Yellowness Index (Y-Z) – as yellowness increases, Y-Z increases

significant, the samples had lower carded YIE values, compared to the scoured value. When evaluating color based on Y-Z values, four samples showed significant improvement after carding while a further 11, while not being significant, showed improved values. As with the case of YIE, a lower Y-Z value indicates a whiter wool.

The yellowness of these wools when scoured ranged from a high of 31.25 to a low of 21.96 (YIE) and a high of 10.63 to a low of 4.93 (Y-Z), while with the carded wools the yellowness ranged from a high of 29.71 to a low of 20.10 (YIE) and a high of 10.05 to a low of 2.72 (Y-Z).

Table 4 shows the Y-Z yellowness indices of scoured and carded U.S., Australian and New Zealand wools by average fiber diameter ranges. Wools from each country were grouped according to fiber diameter into four groups; <20 µm, 20 to 22.9 µm, 23 to 25.9 µm, ≥ 26 µm. Statistical analysis (t-tests) of these fiber diameter groups yielded some interesting results. As was expected, wools from the different countries were not always significantly different in terms of their yellowness. Most of the major differences occurred between U.S. and New Zealand wools or Australian and New Zealand wools. In only one case was U.S. wool significantly different from Australian wool – scoured wools between 20 µm and 22.9 µm.

However, what was of interest in this analysis was the range of yellowness indices, particularly for the scoured wools. The results indicated that U.S. wools had a much wider range of yellowness indices compared to that of both Australian and New Zealand wools. For example, for fiber diameters less than 20 µm; U.S. wools had a mean Y-Z value of 8.82 and the yellowness ranged from 6.59 to 18.91, Australian wools had a mean of 5.96 and ranged from 4.93 to 7.78, and New Zealand wools had a mean of 8.32 and ranged from 6.53 to 9.92. It is unclear how meaningful this result is because of the small number of samples in some of the fiber diameter groupings. More samples are needed to better characterize both U.S. and Australian and New Zealand wool. This is a result that requires additional research using much larger sample sizes. However, if the results were significant they could have ramifications for the selling price of U.S. wools based on color measure-

Table 3. Yellowness indices of scoured and carded Australian wools.

Sample Number	Average Fiber Diameter (µm)	YIE[1]		Y – Z[2]	
		Scoured	Carded	Scoured	Carded
00101	22.1	24.71	22.94	6.41	5.75
00102	23.6	26.26	24.21	7.13	6.36
00103	21.1	25.45	24.14	7.24	6.50
00104	20.9	29.03	26.02*	9.17	8.18
00105	20.4	25.62	24.07	7.47	6.72
00106	24.1	24.96	23.42**	6.94	6.04*
00107	22.1	26.20	25.40	7.63	7.68
00108	36.3	31.25	29.71*	10.63	10.05
00109	23.8	25.96	23.68**	7.6	6.45
00110	20.7	25.30	24.44	7.14	2.72
00111	19.2	26.45	25.67	7.78	7.78
00112	21.1	27.19	27.10	7.58	7.79
00113	20.1	25.01	23.45	6.69	5.45*
00114	18.0	21.96	20.74	4.93	4.18
00115	21.0	23.51	22.72	5.46	4.87
00116	21.0	22.75	20.45**	5.26	3.93*
00117	19.5	22.21	20.73	5.18	4.16
00118	20.2	22.01	20.10**	5.29	3.95**

* $p<0.05$ ** $p<0.01$ *** $p<0.001$

[1] Yellowness Index (YIE) – as yellowness increases, YIE increases

[2] Yellowness Index (Y-Z) – as yellowness increases, Y-Z increases

ments. These measurements, if done, are typically carried out on scoured or otherwise cleaned wool.

We believe that the yellowness values found in this study may not be indicative of the color of wools obtained from the United States, New Zealand or Australia because some of the fiber groupings were underrepresented. A reason for this belief is that as far as fiber diameter is concerned a full range of the wools produced by each country was not evaluated. Further study is needed to better understand the comparative relationships between the color of wools from the different countries. In particular, as well as conducting alkaline scours, all wools also need to be given neutral scours before evaluation. Additionally, further study needs to be done in evaluating wool's susceptibility to yellowing. Two tests have been developed to predict the susceptibility of wool to yellow, one an indirect method the other a direct method. The indirect method – the yellow predictive test (YPT) – developed by Raadsma and Wilkinson (1990) involves incubating wool samples for five days under high humidity. Supernatant is then extracted and the color of the liquid can be used as an indicator or the yellow discoloration of the wool. Aliagra et al. (1996) developed the yellow challenge test (YCT). This is a direct method of evaluating the propensity to wool to yellow. The yellowness of clean wool fibers is evaluated after incubation of grease wool for 14 days under high humidity.

The uniformity and cleanliness of wool grown on different body areas of sheep are major influences on the degree of skirting and wool preparation required (Lupton, et al., 1989). Although wool production and quality control are year-round activities, the manner in which wool is shorn and prepared for sale has an immediate impact

Table 4. Yellowness indice (Y-Z) of scoured and carded U.S, Australian and New Zealand wools by average fiber diameter.

Wool Origin	Average fiber Diameter <20 µm		Average fiber Diameter 20.0 – 22.9 µm		Average fiber Diameter 23.0 – 25.9 µm		Average fiber Diameter 26.0 µm	
	Scoured	Carded	Scoured	Carded	Scoured	Carded	Scoured	Carded
U.S.	N=7	N=7	N=28	N=28	N=10	N=10	N=5	N=5
Average	8.82	6.19	11.38[1,2]	5.51[2]	11.40	5.60[2]	10.80	7.95[2]
Range	6.59-18.91	3.99-7.17	4.17-19.17	2.47-10.46	4.34-20.77	2.57-11.49	7.51-18.37	6.14-10.47
Australia	N=3	N=3	N=11	N=11	N=3	N=3	N=1	N=1
Average	5.96[3]	5.37	6.85[1,3]	5.69[3]	7.22[3]	6.28[3]	10.63	10.05
Range	4.93-7.78	4.16-7.78	5.26-9.17	2.72-8.18	6.94-7.60	6.04-6.45		
New Zealand	N=10	N=10	N=9	N=9	N=5	N=5	N=26	N=26
Average	8.32[3]	7.78	8.57[2,3]	8.49[2,3]	9.69[3]	8.44[2,3]	10.85	10.04[2]
Range	6.53-9.92	5.41-12.50	6.25-11.82	5.17-11.88	8.18-10.27	6.12-10.03	7.05-13.96	6.90-15.69

[1] Australian wool different from U.S. wool ($p<0.001$).

[2] U.S. wool different from N.Z. wool ($p<0.001$).

[3] Australian wool different from N.Z. wool ($p<0.001$).

upon its value and utility to the textile manufacturer. Processing of wool has changed, placing new requirements on fibers. Since 1970, processing rates have increased between 100 percent and 500 percent in almost every stage of worsted processing with the exception of ring spinning, which sustained only a modest increase (Teasdale, 1988). Improved specification of wool will be necessary, especially for processors who do have not extensive wool experience and expertise. Better perception by the mills of their own requirements will be translated into premiums and discounts for particular properties, preparation and marketing methods.

Wools purchased from some overseas suppliers (e.g., in Australia, New Zealand or South Africa) typically do not have to undergo this sorting and grading process because they are prepared by professional skirters and classers in the shearing barn in their respective countries. Thus, these wools are more valuable to the processor. This allows a premium to be paid for wools prepared in this manner.

Processors are paying more attention to the color of wool. A recent study (Cottle and Zhao, 1995) has shown that incubation can bring wool to a more stable color. The color is less likely to change during subsequent storage, scouring or dyeing. Using this information, processors should be able to better predict the processing performance of raw wool (Cottle and Zhao, 1995). A recent development has been a mill-scale, automated-color, sorting device that is capable of sorting large quantities of undyed fibrous material in a continuous on-line operation and removing colored faults, such as stained wool, dark fibers, etc. (Abbott, 1995).

The major wool exporting nations (Australia and New Zealand) place different emphasis on the clean color of wool, with New Zealand placing a high emphasis on clean color, whereas Australia places a lower emphasis (Baxter, 1995). The reason for this is that New Zealand exports more scoured wool than does Australia and therefore the visual appearance of the wool becomes an important characteristic when supplying wool to a customer (Marler, 1992).

Yellow discoloration of wool can be classified as scourable and non-scourable, however, there is no clear distinction between the two (Aitken, et al., 1994). Non-scourable yellow discoloration develops during growth, storage and processing of wool fiber (Winder, et al., 1998). Genetic and environmental factors have been implicated in the yellow discoloration of wool. Wilkinson (1982) found that animals could be classified according to their genetic predisposition to yellow but that environmental factors, such as warmth, humidity and dampness, tended to promote yellowness in genetically susceptible sheep. Non-scourable yellowing was also shown to be prevalent in sheep susceptible to fleece rot (Wilkinson, 1981).

It has been shown that yellow fleeces suffer a significant price discount in international markets (Benavides and Maher, 2000). During the three wool seasons 1996-97 to 1998-99, New Zealand wools, particularly, had Y-Z values ranging from -1.6 to 9.5. Wool up to 30 μm is used primarily in apparel manufacture. Yellow discoloration is of greater importance here than it may be with coarser wools that are used in other applications. During this three-year period, price reductions of up to $NZ 0.10 were observed per Y-Z unit increase (Benavides and Maher, 2000). This translated to an overall price reduction of 16.6 percent for wools having a Y-Z of ≥ 6 compared to those wools with a Y-Z <6 (Benavides and Maher, 2000). Thus there is the potential for significant economic gain for U.S. producers if it can be shown that U.S. wools do not have a propensity to yellow.

Conclusion

It is evident from the results of this study that carding typically improves the color of wool as measured by either YIE value or Y-Z value. This was expected as carding is a further cleaning process and most likely removes dark-colored, extraneous materials, which would otherwise detract from the clean color of the wool.

What was of interest, and warrants further study, is that it appears that while U.S. wools on average may compare favorably, particularly in certain fiber-diameter groupings, the range of yellow color within these diameter groups may be of concern. This could be of significance as far as potential marketing of the wool, both domestically and internationally, especially since yellow fleeces in today's international markets may suffer a significant price discount.

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