# Chemical Composition and Nutritive Value of Dark Hard and Yellow Hard Kernels of Canadian Winter Wheats (*Triticum aestivum* L.) Fed to Laboratory Rats

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## ABSTRACT

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Sixty Sprague-Dawley rats (initial weight 84 g) were randomly assigned to one of 10 treatments in a 21-day growth trial conducted to compare the nutritive value of light and dark kernels of Canadian winter wheats. The experimental diets for this growth trial contained the winter wheat cultivars Yogo, Sundance, Nugaines, Winalta, or Kharkov separated into kernels of light or dark color by a density-gradient method. The diets contained 92.4% wheat, 7.0% vitamin-mineral premix, and 0.6% chromic oxide as a digestibility indicator. Digestibility coefficients for dry matter, energy, and protein were highest for the cultivar Winalta and lowest for the cultivar Sundance. Light-colored kernels had a lower digestibility coefficient for dry matter and energy but a higher digestibility coefficient for protein in comparison with dark-colored kernels. Average weight gain was higher for rats fed the cultivar Sundance (57.6 g) compared with Yogo (44.4 g), with the other cultivars producing intermediate gains. There was no difference in feed conversion efficiency between wheat cultivars. Color of kernel had no significant effect on weight gain, feed consumption, or feed conversion efficiency.

Wheat (*Triticum aestivum* L.) is subject to a physiological condition known as yellow berry, which causes the production of an undesirable, off-color grain. Yellow berries can be distinguished from normal kernels by a softer, lighter-colored, starchy endosperm, which lacks the corneous or vitreous texture characteristic of normal grain (Sharp 1927). The predisposing factors leading to the occurrence of yellow berry in wheat have been reviewed by Headden (1915), Swanson (1935), and Sallans and Simmonds (1954).

Wheat kernels affected by yellow berry have been reported to contain a higher moisture content, a higher percentage of starch, and a lower level of protein in comparison with normal wheat (Roberts 1919). There is little information available concerning how these differences in chemical composition affect the feeding value of the wheat.

Yellow berries have traditionally been separated from normal kernels on the basis of a visual appraisal and hand separation (Dikeman and Pomeranz 1977, Hubbard et al 1977, Waines et al 1978). A less tedious method of separating these kernels has been developed using a density-gradient technique based on chloroform and ethanol (Fenton et al 1985). This experiment was conducted to compare the nutritive value of light and dark kernels of several cultivars of winter wheat separated by density gradient.

## MATERIALS AND METHODS

### Wheat Cultivars

Samples of five cultivars of winter wheat were obtained from various growing locations throughout Alberta. The cultivars obtained were Yogo, Sundance, Nugaines, Winalta, and Kharkov.

### Separation of Kernels

The density of yellow berry kernels has been reported to be lower than that of normal grain (Bailey 1916, Roberts 1919, Sharp 1927). Therefore, based on the principles of hydrometry, it is possible to separate the less dense, light-colored kernels from the dark-colored, higher density kernels of wheat using various concentrations of a chloroform-ethanol solution to set up a density gradient.

When a substance floats in a liquid, it displaces a volume of liquid equal to its own weight. If the body sinks in the liquid, it weighs more than the liquid it displaces. By altering the ratio of chloroform to ethanol in a solution, it is possible to set up a density gradient whereby the light-colored wheat kernels float to the surface and the heavier, dark-colored kernels sink to the bottom of the solution. Occasionally, a wheat kernel will remain suspended in solution. However, by making slight alterations in the ratio of chloroform to ethanol, it is possible to ensure that only light-colored kernels rise to the surface and only dark-colored kernels sink. Details of this procedure have been reported by Fenton et al (1985).

Twenty parts of chloroform were used for each separation, whereas the amount of ethanol used varied with the cultivar to be separated and ranged from 2.4 parts of ethanol for Yogo to 3.2 parts ethanol for Sundance. Previous work has shown that the separation method does not alter the chemical composition or nutritive value of the wheat (Fenton et al 1985).

### Growth Trial

Sixty Sprague-Dawley rats (University of Alberta strain), weighing an average of 84 g at the commencement of the trial, were randomly assigned to one of 10 treatment groups with three males and three females per group. The experimental diets for this growth trial contained the winter wheat cultivars Yogo, Sundance, Nugaines, Winalta, or Kharkov, which had been separated into light or dark kernels by density gradient.

Each of the winter wheats, separated by color, was fed at a level of 92.4%, with vitamins and minerals included in all diets to meet or exceed the rats' nutrient requirements (National Academy of Sciences-National Research Council 1978). The vitamin-mineral supplements used in this experiment have been described in detail by Bowland et al (1984). Each diet also contained 0.6% chromic oxide as a digestibility indicator.

Rats were individually housed in $18 \times 24 \times 18$ cm stainless steel metabolism cages, maintained in an environmentally controlled room (22° C, 45% rh) with automatic lighting which provided 12 hr darkness and 12 hr light. Feed and water were supplied ad libitum. Weight gain and feed consumption were recorded weekly for each rat and summed at the end of the 21-day feeding period to obtain total weight gain and feed consumption for each animal.

The rats were allowed a seven-day adjustment period, which was followed by a 14-day total fecal collection. Feces were collected every second day and were stored at 4° C until the end of the collection period. An aliquot of the combined fecal collection was dried in a forced-air oven at 60° C for 72 hr and ground in a Wiley mill through a 1-mm mesh screen.

### Chemical Analyses

Analyses for nitrogen and dry matter were carried out according

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to the Association of Official Analytical Chemists (AOAC 1975). Kjeldahl nitrogen was converted to protein using the conversion factor 5.7. Combustible energy was determined using a Parr adiabatic oxygen calorimeter. Chromic oxide was determined by the method of Fenton and Fenton (1979). Digestibility of nitrogen and energy were determined by the method of Sibbald et al (1957).

**Statistical Analysis**

Analyses of variance involving an equal number of observations were conducted according to the procedures given by Steel and Torrie (1960). Means for significant treatment differences were compared using the Student-Newmann-Keul's multiple-range test (Steel and Torrie 1960).

## RESULTS AND DISCUSSION

The percentage of yellow berries in the winter wheat cultivars was 25.2% for Yogo, 34.6% for Kharkov, 58.3% for Winalta, 78.5% for Nugaines, and 84.6% for Sundance. The occurrence of yellow berry has been shown previously to be cultivar related (Dikeman and Pomeranz 1976, Wiese 1977).

Chemical analyses of the winter wheat cultivars are presented in Table I. The dry-matter content of the winter wheat cultivars ranged from 90.3% (Sundance dark) to 95.5% (Winalta light). The relatively high dry-matter content of all samples reflected air drying that occurred during storage. The protein content of the winter wheat cultivars ranged from 11.5% (Nugaines dark) to 14.6% (Kharkov light). These values are similar to previously reported assays for winter wheat cultivars (National Academy of Sciences 1972).

Kernel color had no consistent effect on protein content of the winter wheats. This observation does not support previous work that reported wheat kernels affected by yellow berry contain a lower level of protein in comparison with normal wheat (Waines et al 1978, Dikeman and Pomeranz 1977, Hubbard et al 1977).

The apparent digestibility of dry matter for the cultivars Sundance and Kharkov was significantly lower ($P<0.05$) than that of the other cultivars (Table II). Digestibility coefficients for dry matter were 88.9% for Winalta, 88.7% for Yogo, 88.5% for Nugaines, 88.0% for Kharkov, and 86.9% for Sundance. The apparent digestibility of dry matter was significantly higher ($P<0.05$) for the dark-colored kernels of wheat in comparison with the light-colored kernels.

Digestibility coefficients for protein were 82.5% for Sundance, 83.5% for Yogo, 83.7% for Nugaines, 84.3% for Kharkov, and 85.2% for Winalta. Light-colored kernels had a significantly higher ($P<0.05$) protein digestibility in comparison with dark-colored kernels.

The digestible energy coefficient for the cultivar Sundance was significantly lower ($P<0.05$) than that of the other cultivars. Digestibility coefficients for energy were 88.3% for Winalta, 88.2% for Yogo, 88.0% for Nugaines, 87.9% for Kharkov, and 87.2% for Sundance. Light-colored kernels had a significantly lower ($P<0.05$) digestibility coefficient for energy in comparison with dark-colored kernels. Digestibility coefficients for dry matter, protein, and energy did not differ between males and females.

During the 21-day feeding trial, the feed consumption of rats fed the cultivar Sundance was significantly higher ($P<0.05$) than that of rats fed the other cultivars (Table III). Rats fed the cultivar Sundance consumed 283.6 g of feed compared with 243.8 g for those fed Winalta, 241.7 g for Kharkov, 237.6 g for Nugaines, and 224.6 g for Yogo. Male rats consumed significantly more food than female rats ($P<0.05$). Kernel color did not affect the food consumption of rats.

The lower digestibility of dry matter, protein, and energy for rats fed the cultivar Sundance may be explained by their higher feed intake. An increase in the quantity of feed consumed by an animal generally causes a faster rate of passage of digesta. The feed is then exposed to the action of digestive enzymes for a shorter period of time, thereby reducing its digestibility.

Weight gain was higher for rats fed the cultivar Sundance (57.6 g) compared with Yogo (44.4 g), with the other cultivars producing intermediate gains. Male rats gained significantly faster than female rats ($P<0.05$), whereas color of kernel did not affect the weight gain of rats.

Differences in growth rate between rats fed the various winter wheat cultivars were largely the result of differences in feed intake and did not appear to be related to the protein content of the winter wheats. This can be explained by previous work from our

**TABLE I**
**Chemical Analysis of Winter Wheat Cultivars[a]**

| Cultivar | Dry Matter (%) | Crude Protein (%) | Gross Energy (MJ/kg) |
|---|---|---|---|
| Sundance light | 93.0 | 12.6 | 16.9 |
| Sundance dark | 90.3 | 13.1 | 17.4 |
| Nugaines light | 94.6 | 12.5 | 16.6 |
| Nugaines dark | 93.6 | 11.5 | 16.7 |
| Yogo light | 94.0 | 12.8 | 16.7 |
| Yogo dark | 94.0 | 12.6 | 16.6 |
| Winalta light | 95.5 | 14.0 | 16.5 |
| Winalta dark | 94.9 | 12.7 | 16.7 |
| Kharkov light | 94.0 | 14.6 | 16.7 |
| Kharkov dark | 95.0 | 13.4 | 16.4 |

[a] As fed.

**TABLE II**
**Effects of Cultivar, Color, and Sex on the Digestibility of Winter Wheats[a]**

| | Dry Matter (%) | Protein (%) | Energy (%) |
|---|---|---|---|
| Cultivar | | | |
| Sundance | 86.9 a | 82.5 a | 87.2 a |
| Nugaines | 88.5 c | 83.7 ab | 88.0 b |
| Yogo | 88.7 c | 83.5 ab | 88.2 b |
| Winalta | 88.9 c | 85.2 c | 88.3 b |
| Kharkov | 88.0 b | 84.3 bc | 87.9 b |
| SE | 0.2 | 0.4 | 0.2 |
| Color | | | |
| Light | 87.8 a | 84.0 b | 87.4 a |
| Dark | 88.5 b | 83.7 a | 88.4 b |
| SE | 0.1 | 0.2 | 0.1 |
| Sex | | | |
| Male | 88.3 a | 83.9 a | 88.0 a |
| Female | 88.1 a | 83.8 a | 87.9 a |
| SE | 0.1 | 0.2 | 0.1 |

[a] Within cultivar, color, or sex, means followed by the same letter do not differ ($P<0.05$).

**TABLE III**
**Effects of Cultivar, Color, and Sex on the 21-Day Performance of Rats Fed Winter Wheats[a]**

| | Intake (g) | Gain (g) | Feed Conversion |
|---|---|---|---|
| Cultivar | | | |
| Sundance | 283.6 a | 57. 6 b | 4.96 a |
| Nugaines | 237.6 b | 48.8 ab | 4.92 a |
| Yogo | 224.6 b | 44.4 a | 5.07 a |
| Winalta | 243.8 b | 53.0 ab | 4.63 a |
| Kharkov | 241.7 b | 52.3 ab | 4.73 a |
| SE | 8.5 | 2.4 | 0.11 |
| Color | | | |
| Light | 250.7 a | 52.8 a | 4.82 a |
| Dark | 242.7 a | 49.0 a | 4.89 a |
| SE | 5.4 | 1.5 | 0.07 |
| Sex | | | |
| Male | 253.8 b | 54.6 b | 4.69 a |
| Female | 239.7 a | 48.2 a | 5.02 b |
| SE | 5.4 | 1.5 | 0.07 |

[a] Within cultivar, color, or sex, means followed by the same letter do not differ ($P<0.05$).

TABLE IV
Amino Acid Composition of Light and Dark Kernels of Sundance Winter Wheat[a]

| Amino Acid | Light | Dark |
|---|---|---|
| Indispensable | | |
| Arginine | 0.57 | 0.59 |
| Histidine | 0.30 | 0.31 |
| Isoleucine | 0.46 | 0.49 |
| Leucine | 0.89 | 0.93 |
| Lysine | 0.37 | 0.37 |
| Methionine | 0.22 | 0.20 |
| Phenylalanine | 0.70 | 0.67 |
| Threonine | 0.39 | 0.41 |
| Valine | 0.58 | 0.61 |
| Dispensable | | |
| Alanine | 0.47 | 0.48 |
| Aspartic Acid | 0.64 | 0.65 |
| Cystine | 0.18 | 0.15 |
| Glutamic Acid | 3.96 | 4.17 |
| Glycine | 0.52 | 0.54 |
| Proline | 1.74 | 1.60 |
| Serine | 0.61 | 0.62 |
| Tyrosine | 0.28 | 0.28 |

[a]% Dry matter.

laboratory which indicated that although differences in protein content exist between these winter wheat cultivars, there is little difference in their essential amino acid content (Bowland et al 1984). In addition, analysis of the cultivar Sundance indicated little difference in amino acid composition between light and dark kernels of winter wheat (Table IV).

Feed conversion efficiency was not significantly affected by cultivar or color of kernel. However, male rats had improved feed efficiencies in comparison with female rats.

The overall results of this study indicate that light-colored kernels of winter wheat have a lower digestibility coefficient for dry matter and energy but a higher digestibility coefficient for protein in comparison with dark-colored kernels of winter wheat. However, these changes in digestibility were not reflected in the performance of rats fed light or dark kernels of winter wheat.

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