Management Practices to Maintain Dry Bean Grain Quality

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ABSTRACT

Dry bean (*Phaseolus vulgaris* L.) quality deteriorates in storage. With time, seeds become harder, increasing cooking time, and light-colored seedcoats tend to darken, compromising appearance. Growers are interested in on-farm storage to improve marketing options, but need information on proper storage conditions to maintain quality. This research was conducted to quantify the effects of harvest moisture content, storage temperature and moisture content, ultraviolet light exposure, and time on bean quality. Pinto bean cv. 'Maverick' was sown in 1999 and samples were harvested periodically during drydown to determine quality deterioration in the field. The bulk of the crop was straight-combined at 190 g kg^{-1} grain moisture for imposition of storage treatments. After 120 d at 180, 160, and 140 g kg^{-1} moisture, beans stored at 27°C (summer temperature) were much darker and had longer pin cooking times than those stored at 4°C. The degree of darkening increased with moisture content. Beans stored at 180 g kg^{-1} moisture and 4°C were lighter colored than those stored at 140 g kg^{-1} moisture and 27°C, indicating the importance of temperature in maintaining color. Ultraviolet light dramatically and rapidly darkened the beans, suggesting that the surface area exposed to light should be minimized. Slight darkening occurred in the field as the beans dried from 200 to 130 g kg^{-1} moisture, but no precipitation events were recorded during this period.

Keywords: Phaseolus vulgaris L., storage, harvest, quality

INTRODUCTION

North Dakota is the leading dry bean production state in the U.S.A. (USDA, 2000). Currently, the majority of the crop is marketed at harvest, but producers are interested in on-farm storage to improve marketing options. However, dry bean (especially pinto bean) quality (color and hard-seededness) readily deteriorates in storage.

Survey of Dry Bean Growers / Handlers / Processors. A survey of numerous dry bean growers and more than 50 handlers / processors revealed a wide variety of procedures for handling, processing, storing, and determining bean quality (K. Hellevang, unpublished data). Light was listed by 42% of the processors as a factor causing bean color change and 34% indicated that moisture content was a factor. Temperature, humidity, age, and cleaning were indicated as factors by only 10% of the processors.

Color Change. Processing and storage methods affect the color of pinto beans (Cai and Chang, 1997). Uebersax and Bedford (1980) observed that Hunter-L values (an indicator of lightness; lower values = darker) decreased with increased relative humidity, storage time and temperature. The greatest change occurred in beans stored for 84 days at 29°C and 93% and 100% relative humidity. Hunter-a_L (redness) and -b_L (yellowness) values increased with increased relative humidity, temperature and storage time. These changes in Hunter values generally correspond to non-enzymatic browning of beans.

Mold Growth. Mold growth is partially responsible for color changes at higher temperatures and humidities. Unless the temperature or moisture concentration is lowered, storage fungi will continue to grow and eventually cause germ damage, heating, caking, bin-burning, and mustiness. The ability of fungi to invade the seed coat of dry beans is directly related to moisture concentration, temperature, and storage period. Mold growth during storage increases with an increase in relative humidity, storage temperature and time in the 79% to 100% humidity range (Uebersax and Bedford, 1980). At 75% relative humidity (160 g kg^{-1} grain moisture), mold growth occurs at temperatures of 12°C or higher and maximum growth occurs at 20°C.

Hard-to-Cook Phenomenon. A major drawback to the utilization of dry beans is their decreased cookability after storage at high temperatures and humidities (Jackson and Varriano-Marston, 1981). Increased cooking times have been related to the development of two types of "hardshell:" (1) seed coat impermeability and (2) cotyledon impermeability. In the former, removing the seed coat or scarifying alleviates the problem.

During bean cooking, the water absorption capacity is an important and integral part of softening (Cai and Chang, 1997). Soaking recently harvested beans in water before cooking significantly lowers cooking time. Barron, et al., found that pinto beans showed a significant decrease in water absorption capacity, related to the increase in cooking time, after 5 months of storage at 30°C. This decrease was not observed in subsequent months. They also found a positive correlation between cooked bean texture and water absorption capacity for pressure cooked beans stored at 30°C and 45% relative humidity.

Srisuma, et al. (1989) found that the major hydroxylcinnamic acids found in stored navy beans were ferulic, sinapic, and p-coumaric. The development of the Hard-to-Cook phenomenon was best associated with large increases in free hydroxycinnamic acids. No significant changes in lignin content of either seed coat or cotyledon were detected. Increases in hydroxycinnamic acid content of protective tissues, like seed coats, leads to increased discoloration and toughness.

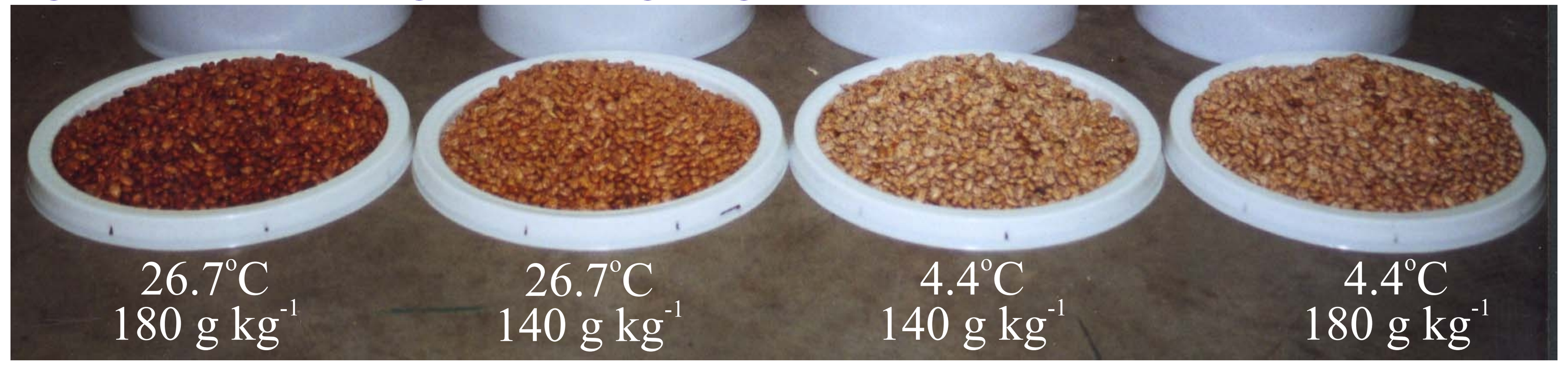
Moisture Effect. The moisture content of beans is an important factor influencing the stability of quality during storage (Swanson, et al., 1977; Morris and Wood, 1956; McCurdy, et al., 1980). Morris and Wood (1956) found that, above 130 g kg^{-1} moisture content, beans deteriorate significantly in flavor and texture in six months at 25°C. Beans below 100 g kg^{-1} moisture maintained their quality for two years at 25°C. Burr, et al. (1968) found that in 12 months beans became very unpalatable in flavor and texture, declined in catalase and phosphatase activity, increased in respiration, increased in cooking time, darkened in color, and increased significantly in lipid acid value. Increases in lipid acid value indicate reduced organoleptic quality.

Moisture levels in storage also affect nutritional value. Burr, et al. (1968) found a substantial loss of thiamine during storage and this loss was progressively greater at higher moisture contents. Niacin seems to retain well at all moisture levels.

The critical level for spoilage is when the moisture concentration of the bean reaches equilibrium with an atmospheric relative humidity of 75%, which occurs at 163–167 g kg^{-1} grain moisture (Swanson, et al., 1977). Fungal growth will readily occur at dry bean moisture concentrations greater than 180 g kg^{-1}.

Heat Effect. Pinto beans are harvested in the fall and stored in unheated warehouses (Swanson, et al., 1977). Beans in bulk storages are subject to considerable temperature fluctuation, which leads to increased relative humidities in air spaces and favors chemical deterioration and growth of microorganisms. The rate of bean deterioration and spoilage is slow under good storage conditions, but considerable loss of quality occurs under unfavorable conditions.

Figure 1. Relative darkening of beans during storage.



OBJECTIVES

The objectives of this research were to identify the principal factors which contribute to dry bean grain quality deterioration. The variables studied included:

- ★ Timeliness of harvest,
- ★ Storage moisture,
- ★ Storage temperature,
- ★ Exposure to UV light in storage, and
- ★ Duration of storage.

MATERIALS AND METHODS

Pinto bean (*Phaseolus vulgaris* L.) cv. 'Maverick' was sown on a Heimdahl silt loam soil at the North Dakota State University Carrington Research Extension Center on 1 June 1999. A seeding rate of 173,000 live seeds ha^{-1} was used with a row spacing of 0.76 m. Normal best management practices were employed during the growing season.

Field Weathering Study. As the beans approached harvest moisture, periodic samples were collected, placed in plastic bags to maintain the moisture content and paper bags to prevent light exposure, and stored in a refrigerator prior to color measurements. At weekly intervals, color was measured using a Hunter lab colorimeter to determine Hunter-L values (whiteness / lightness), Hunter-a values (redness), and Hunter-b values (yellowness).

Storage Study. Beans were harvested at 190 g kg^{-1} moisture content. Sublots were dried to 140, 160, and 180 g kg^{-1} moisture content using low temperature drying (the air was heated approximately 1.5°C). The moisture content was measured using a Motomco Moisture Meter model 919 and verified using oven drying (ASAE Standard S352.2, Dec97). Four replicates of beans at each of the three moisture levels were stored for eight months in controlled atmosphere in covered, 19 liter pails at temperatures of 4.4 or 26.7°C. The higher temperature represented summer storage and was maintained with electric heaters and a thermostat in an insulated box. The lower temperature was cold enough to minimize mold growth and still be above freezing and was maintained in a walk-in cooler. A Hunter lab colorimeter was again used to measure color of three subsamples each from three or four replicates of each treatment. Readings were taken at monthly intervals for eight months.

Beans at 160 g kg^{-1} moisture content were exposed to ultraviolet light to determine the effect of light on bean color. Ultraviolet light was used, since this was the light spectrum expected to most affect color. The beans were placed in a shallow layer, approximately 1 cm deep, inside an insulated box, which was maintained at 26.7°C. A Phillips 20 watt black light bulb was used to provide the ultraviolet light. Color was determined at weekly intervals over a 2-month period.

RESULTS AND DISCUSSION

Standard deviations ranged from 0.2 to 0.4 for Hunter-L values, 0.1 to 0.2 for Hunter-a values, and 0.05 to 0.15 for Hunter-b values.

Field Weathering Study. Some darkening of the pinto beans occurred in the field as harvest moisture decreased. Hunter-L values of 49.2 for beans harvested on September 24th (200 g kg^{-1} moisture) decreased, indicating darkening, to 47.2 for those harvested on October 11th (130 g kg^{-1} moisture). During this period, Hunter-a values increased from 4.7 to 5.3, indicating an increase in the redness. No change was observed in the Hunter-b value, which indicates yellowness. Maturation conditions were ideal during this period, with rapid drydown and no precipitation, so little weathering occurred in the field.

Storage Study. Beans exposed to ultraviolet light darkened dramatically (Hunter-L) in two months of storage (Table 1). The color darkened more quickly at the beginning of the storage period. Hunter-a values indicated an increase in redness, while Hunter-b values indicated little change in the yellowness.

These results indicate a need to minimize exposure to light in storage and possibly even before storage. Approximately 70% of bean handlers use flat storage, which exposes a large surface area to potential discoloration by exposure to light.

Table 1. Hunter colorimeter values for 160 g kg^{-1} moisture content beans exposed to ultraviolet light at 26.7°C (80°F).

Date	Hunter-L (White)	Hunter-a (Red)	Hunter-b (Yellow)
10/18/99	49.2	4.5	9.3
10/25/99	48.7	4.8	9.5
10/29/99	47.9	5.0	9.4
11/5/99	47.4	5.3	9.6
11/12/99	47.4	5.0	9.4
11/19/99	46.5	5.3	9.5
11/26/99	46.2	5.5	9.7
12/3/99	45.5	5.8	9.6
12/10/99	45.6	5.7	9.7
12/17/99	45.1	5.7	9.6

Dramatic differences in bean lightness (whiteness) were observed in response to the various storage temperature and moisture treatments (Table 2 and Figure 1). Beans stored at 4.4°C and 140 g kg^{-1} moisture content showed only a minor decrease in color quality. In contrast, beans stored at 26.7°C and 180 g kg^{-1} moisture content decreased in L-value from 49.2 to 36.0. When stored at 4.4°C, there was little difference in color quality after eight months storage at the various moisture contents. At 26.7°C, color lightness of the higher moisture content beans deteriorated more than that of the drier beans.

Table 2. Hunter-L values (whiteness) for specified storage conditions of temperature and moisture content.

	4.4 C (40 F)			26.7 C (80 F)		
Date	140g kg^{-1}	160g kg^{-1}	180g kg^{-1}	140g kg^{-1}	160g kg^{-1}	180g kg^{-1}
10/18/99	49.2	49.2	49.2	49.2	49.2	49.2
11/5/99	49.0	48.2	48.6	48.2	47.0	46.8
12/17/99	48.3	47.7	47.6	43.6	44.4	46.2
1/14/00	48.3	47.7	48.2	45.6	43.5	42.0
2/25/00	47.5	47.3	47.2	43.8	41.5	39.5
3/17/00	47.5	45.7	45.6	43.4	40.3	38.7
4/28/00	48.1	47.1	47.6	43.3	39.4	38.2
5/15/00	47.9	46.3	47.1	42.2	39.7	37.3
6/29/00	47.2	47.3	47.1	41.4	38.5	36.0

As indicated by the Hunter-a values, there were dramatic storage temperature and moisture treatment effects on bean redness (Table 3). At 4.4°C, there was little difference in color quality at the various moisture contents after storage for eight months. In contrast, at 26.7°C, a drastic increase in redness was observed, with the higher moisture content beans deteriorating more in color than the drier beans.

Table 3. Hunter-a values (redness) for specified storage conditions of temperature and moisture content.

	4.4 C (40 F)			26.7 C (80 F)		
Date	140g kg^{-1}	160g kg^{-1}	180g kg^{-1}	140g kg^{-1}	160g kg^{-1}	180g kg^{-1}
10/18/99	4.5	4.5	4.5	4.5	4.5	4.5
11/5/99	4.5	4.5	4.6	4.8	5.1	5.2
12/17/99	4.7	4.9	4.9	6.6	6.1	5.6
1/14/00	4.8	4.9	4.9	6.0	6.5	7.2
2/25/00	4.9	5.0	5.1	6.4	7.1	7.9
3/17/00	5.3	5.6	5.8	6.7	7.5	8.2
4/28/00	4.7	4.6	4.8	6.5	7.6	8.0
5/15/00	4.6	4.7	4.8	6.9	7.5	8.2
6/29/00	4.7	4.7	4.8	7.0	8.1	8.6

No treatment effects or trends were observed on Hunter-b (yellowness) values for beans during the 8-month storage period (data not shown).

The pinto beans were checked for the hard-to-cook characteristic (shorter cooking times are desired) after four months of storage (Table 4). There was a dramatic difference in cooking times for the various treatments. Beans that were stored at 26.7°C had cooking times that were two to four times longer than those stored at 4.4°C. The beans that had decreased in color quality (decreased lightness and increased redness) had much longer cooking times.

Table 4. Pin cooking times for beans stored for four months at specified moisture contents and temperatures.

Moisture Content (g kg^{-1})	Temperature (°C)	(°F)	Cooking Time (minutes)
18	26.7	80	102
16	26.7	80	112
14	26.7	80	76
18	4.4	40	28
16	4.4	40	32
14	4.4	40	49

CONCLUSIONS

It is extremely important to store pinto beans at cool temperatures and in the absence of UV light to maintain color and cooking quality. Beans should be cooled as rapidly as possible using aeration. If bean temperature cannot be cooled, then pinto beans likely need to be stored at moisture contents of approximately 130 g kg^{-1} or drier. Even then, the storage period will be shorter than beans stored at cool temperatures.

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