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Harvest of Dry Beans in the Pre-Dry Stage of Development: Effect on Yield and Processed Product Quality[1]

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Abstract. **The effect of time of harvest prior to complete field drying of 2 cultivars of dry bean (*Phaseolus vulgaris* L.) was analyzed relative to the quality of the processed product produced. Early harvest did not significantly affect yield (at 10% raw product moisture); however, it did have a significant effect on the quality of the processed product. Typically the processed dark red kidney and pinto beans were more intensely pigmented with later harvest dates, were firmer, and had fewer split seeds. The respiratory rate of the raw product was highly correlated (r = 0.993) with the raw product moisture level. Only small differences were found in the degree of pigmentation of the processed product when comparing the spring with the fall crop of pinto beans. The fall crop of pinto beans had a substantially lower incidence of split beans in the canned product.**

In a number of dry bean production areas, the close proximity of processors would allow the harvest and processing of dry beans prior to the beans reaching a field dry state. Early harvest followed by immediate processing has distinct advantages: (a) during unseasonably wet weather beans can be harvested and processed without artificial drying; (b) elimination of field drying could extend production into some regions where precipitation during the field drying period prevents the commercial culture of the crop due to seed discoloration and/or rot (4, 5, 9, 10); (c) it allows for earlier planting of the second crop in a multiple cropping sequence; and (d) in addition to possible raw product economic considerations, it makes for greater flexibility in scheduling of peak work loads between crops in the sequence of crops processed at a respective plant.

The potential for early harvesting of dry beans has been looked at previously, however, only in conjunction with subsequent field drying of the raw product (2, 6, 7). In general, 'Dark Red' kidney beans that had reached at least 50% seed moisture did not sustain yield and seed size losses when harvested prior to complete field drying, but harvesting beans at higher moisture contents often reduced yield. Early harvest has been shown to be advantageous in that seed quality as measured by percent germination and the percent of split seeds after processing is improved.

The effect of early harvest of dry beans on processed product quality when the raw product is processed without field or supplemental drying has not been ascertained. The objective of this study was to determine the effect of early harvest on yield and quality components of the processed product when the raw product was processed prior to reaching a field dry state. In addition, the need for possible changes in postharvest handling techniques were analyzed.

Materials and Methods

Production. Dry bean cultivars 'Dark Red' kidney and 'UI 111' pinto were grown during the spring and fall of 1976 at Fayetteville, Arkansas. Fertilization included a preplant application of 616 kg/ha of 10N-16.6P-4.3N and 112 kg/ha of ammonium nitrate as a sidedress at anthesis. EPTC (3.4 kg active/ha) and Trifluralin (0.67 kg active/ha) were incorporated prior to planting. Plants were seeded in 107 cm rows with either 20-26 plants/m of row (kidney) or 26-33 plants/m of row (pinto). Four replications of 9.1 m rows for each of 4 harvest dates per cultivar were grown. Beans were hand harvested at the appropriate harvest date and machine shelled. Initial harvest was when about 10-15% of the pods/m of row began to dry. Subsequent harvests were made at 7 day intervals.

Raw product respiration rate. Respiratory measurements were made at 21°C on replicated 150 g samples contained in sealed glass jars (473 cc) with a flow rate of 50 ml/min of humidified air. One ml gas samples were analyzed twice daily over a 3 day period using a Hamilton Fisher Model 29 gas partitioner (TC detector). Individual gas samples were separated on a 1.8 m × 6.4 mm column of 30% DEHS on Columnpak, 60-80 mesh and 2.0 m × 4.8 mm column of 42-60 mesh Molecular Sieve 13X. Raw product respiration was measured only on the fall crop.

Processing. Samples from each replication were cleaned with a roller washer, blanched for 5 min (water blanch) at 82°C and filled in 211 × 304 C enamel cans. Fill weight per can was based on the sample moisture content so that after processing and storage all cans contained approximately the same weight of product. The blanched beans were covered with a 2% NaCl brine, the cans sealed and the beans processed at 117° for 38 min in a steam retort and cooled to 35-40° in cold tap water.

Processed product quality analysis. Quality parameters of the processed product were measured after about 3 months storage of the cans. Number of split seeds/100 g, product color and shear were determined. Product color was determined using a Gardner CDM against the standard white chromatic reference ("L" = 92.1, "a" = 1.4, "b" = 1.7). Texture as determined by the force required to shear a 150 g sample was measured using FTC Shear Press, model TP-1A, with a 453 kg load cell operated a 72.6 kg pressure with a 11 sec down stroke.

Results

Higher fresh weight yields of pinto beans were associated with the earlier harvests (Table 1), but the weight of beans when corrected for moisture differences at each harvest date was not significantly decreased. The 'Dark Red' kidney cultivar did not have a significant depression in yield (at 10% moisture) when harvested early. The moisture content of the beans progressively decreased with later harvest dates for both cultivars, however, the rate of moisture loss varied between cultivars. The pinto cultivar decreased in field moisture content at a more progressive rate than did the 'Dark Red' kidney. It should be noted, however, that the harvest dates for each cultivar did not coincide; hence, rate differences may be reflecting a climatological variation rather than inherent cultivar maturity differences.

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Table 1. Effect of time of harvest and cultivar on the yield and processed product quality attributes of dry beans harvested in the pre-dry stage.

Variable	Date of harvest[z]							
	Pinto beans (Fall 1976)				Kidney beans (Fall 1976)			
	1	2	3	4	1	2	3	4
Total yield (kg/ha)	2964	2194	1129	1332*	2615	2824	1766	1797*
Yield at 10% product moisture (kg/ha)	1476	1481	1050	1268^{ns}	1310	1581	1457	1504^{ns}
Raw product moisture (%)	60.2	42.5	17.0	14.8**	59.9	54.0	27.5	26.3**
Raw product respiratory rate (mg CO_2/kg·hr)	351.4	155.9	4.8	1.4**	373.0	236.3	21.0	20.1**
Processed product quality color								
L	46.0	42.8	38.0	37.7**	24.9	23.2	21.0	20.1**
a	6.6	6.9	8.2	8.3**	9.2	9.8	9.4	8.8^{ns}
b	14.8	14.1	13.4	12.9**	3.5	2.7	3.4	3.4^{ns}
Shear[x] (kg/125 g)	67.9	86.8	127.5	117.3**	68.4	70.4	116.1	114.8**
Split seeds (no./100 g)	26.5	9.9	5.7	3.5**	16.2	20.4	10.4	4.8**

[z]7 day intervals.

[x]kg of force required to bring 125 g of processed beans to yield point.

*, **Statistically significant differences within cultivars at the 5% (*) or 1% (**) levels.

High respiratory rates of the beans can critically diminish the quality of the processed product if delays occur between harvest and removal of field heat and/or processing. The rate of respiration, measured at 21°C, decreased with decreasing product moisture content (Fig. 1). This response was linear between 60 and 15% moisture (r = 0.993). Under commercial conditions it is generally considered safe to begin harvesting beans when they reach 30% moisture. This level of raw product moisture would coincide with approximately 100 mg CO_2/kg·hr. In addition, as the raw product approaches a moisture level acceptable for the long term storage of dry beans (i.e., 12-15%), the respiratory rate becomes extremely low (Table 1).

Analysis of the processed product harvested in varying stages of maturity reveals a significant decrease in the CDM L values for both cultivars which is indicative of a darker or more intensely pigmented final product (Table 1). Pigmentation of 'Dark Red' kidney beans changed from a light pinkish-red through a dark pinkish-red to a dark red between the first and the fourth harvest. In the pinto cultivar, CDM "a" (redness) increased and the CDM "b" (yellowness) decreased with later harvests. No significant differences were found for either "a" or "b" values with the 'Dark Red' kidney cultivar. Measurement of shear values of the processed product indicated a significant increase for both cultivars with the later harvest dates (Table 1). This indicates that beans harvested at the earlier harvest dates yielded a softer product after processing than did those beans harvested at the later dates. Whether this will affect the maintenance of the integrity of the individual processed beans during shipping and storage awaits additional study. In addition, the number of split seeds in the processed product decreased with later harvest dates (Table 1).

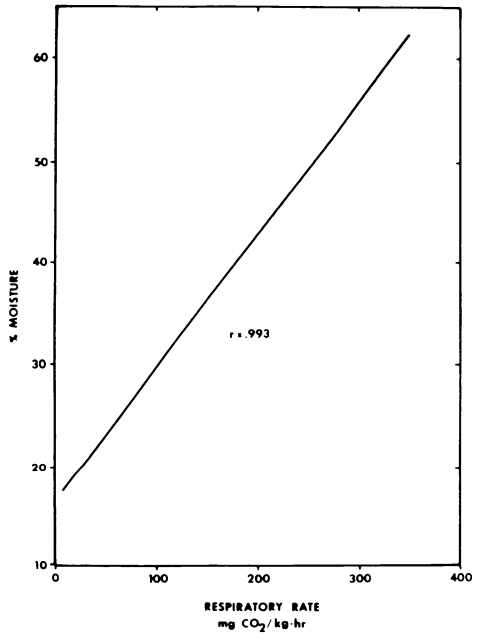

Fig. 1. The relationship between the moisture content and the respiratory level of the raw product at 21°C.

Table 2. Effect of season and cultivar on the yield and processed product quality attributes of dry beans harvested in the pre-dry stage.

Variable	Pinto beans		Kidney beans	
	Spring	Fall	Spring	Fall
Total yield (kg/ha)	2370	1701**	1612	2095**
Yield at 10% product moisture (kg/ha)	2139	1038**	1524	1213**
Raw product moisture (%)	15.5	33.2**	16.0	42.5**
Color				
L	41.6	42.8^{ns}	19.2	20.1^{ns}
a	5.3	6.9**	7.3	8.8^{ns}
b	12.5	14.1**	2.6	3.4^{ns}
Shear (kg/125 gm)	86.6	86.8^{ns}	118.8	114.8^{ns}
Split seeds (no./100 gm)	29.6	9.9**	2.3	4.8^{ns}
Raw product moisture of harvest dates compared for processed product quality	38.4	42.5^{ns}	28.7	26.3^{ns}

[z]Comparisons made between a spring and fall harvest date having comparable raw product moisture levels.

[x]kg of force required to bring 125 g of processed beans to yield point.

**Significant differences within cultivars at the 1% level.

Table 3. Correlation coefficients between percent bean moisture content at harvest and processed product color evaluation (CDM L, a, b).

Cultivar	r value		
	L	a	b
Dark Red Kidney	0.87	0.66	0.16
Pinto	0.89	−0.63	0.43

Since 2 crops of beans are typically produced per year in the Northwestern Arkansas area, it was of interest to compare the results of the spring with the fall seasons regarding dry bean field production and the processed product. Pinto beans grown in the spring season had significantly greater yields (both total yield and yield at 10% moisture) with a lower average moisture content than the fall crop (Table 2). The greatest total yield of kidney beans, however, was produced with the fall crop. This difference was due to the high raw product moisture level. When the yields of the kidneys were corrected to 10% moisture, the spring crop of beans had the greater yield as did the pinto cultivar.

Processed product quality attributes were correlated to varying degrees with raw bean moisture content (Table 3). In order for meaningful comparisons of quality to be made between seasons, it was necessary to analyze differences in quality between harvest dates in the spring and fall which had essentially equal raw bean moisture contents. The differences in harvest dates between the spring and fall with the closest raw product moisture levels were 4.1% for the pinto bean cultivar and 2.4% for the 'Dark Red' kidney cultivar (Table 2). The differences in moisture between the 2 dates were not significant at the 5% level. No statistically significant differences were found between the processed product quality attributes of kidney beans between the spring and fall production seasons. With the pinto cultivar, however, there was a significant difference in CDM "a" and "b" values indicating differences in pigmentation between beans grown in the spring and fall. In addition the number of split beans in the fall crop was substantially less.

Discussion

The results of this study indicate that substantial differences in the quality of the processed product were obtained with early harvest and processing of dry beans. These differences center primarily around the intensity of pigmentation of the processed beans, their texture values and the number of split seeds. Processed beans of both cultivars darkened in color when harvested at later maturities. The 'Dark Red' kidney cultivar progressed from a pinkish-red to a dark red with later harvests. Color changes in the pinto cultivar include an intensification of color in the brown pigmented areas and a gradual change from white to cream color of the light colored regions of the seed. Shear values, a measure of the firmness of the processed product, increased with later harvest dates. The extent to which a softer product may contribute to structural integrity losses during storage, shipping and marketing is not known. The number of split seeds, an important measure of processed product quality, also decreased with later harvest dates. A distinct advantage is therefore realized with later harvest.

As documented in previous studies (3, 6, 7), dry matter yield of raw beans did not decrease when beans were harvested early. The respiratory rate decreased rapidly with decreasing raw product moisture level. Serious handling problems could occur, however, with beans harvested with between 30 to 60% moisture. The relatively high product temperature at harvest, closeness of packing of the shelled beans and high respiratory rates could result in anaerobic conditions and heat build-up favoring off-flavor development, fungal growth and detrimental changes in the physio-chemical properties of the beans. Delays of 7 or more hours between harvest and processing are not uncommon in some production areas where southernpeas (*Vigna unguiculata* [L.] Walp) are harvested in the pre-dry stage of development (8). The use of dry beans harvested between 30 to 60% product moisture would be distinctly facilitated by the close proximity of the processor and precise scheduling of the harvesting-transport-processing sequence. The commercial practice of not harvesting dry beans until the raw product moisture level is equal to or less than 30% coincides with respiratory rates of equal to or less 100 mg CO_2/kg·hr.

Of the quality attributes which are found to decrease with early harvest of these cultivars, only the number of split seeds can be said with certainty at this time to be a critical flaw in the potential for early harvest. The extent of the negative effect of variations in color and shear of the processed product await analysis of their effect on consumer organoleptic and esthetic acceptance. In addition, the affect of a softer processed product on the physical decomposition of the individual beans during transit and storage must be ascertained.

It is also evident from this study that the season of the year can also have an effect on the quality of the processed product of some cultivars. Although during the spring season a higher quality product, especially with regard to the number of split beans, was produced in Northwestern Arkansas, these results may not be similar in other areas of the United States.

Early harvesting and processing of dry beans provides an alternative to normal harvesting and processing procedures. While many advantages are apparent, we have demonstrated, however, that the use of early harvest is not without trade-offs in quality of the processed product. Ascertaining the impact of these trade-offs in quality on consumer acceptance and determining, through additional research, the extent to which these quality losses can be eliminated will greatly affect the extent to which early harvest is accepted on a commercial basis.

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