Use of Friction Debranning to Evaluate Ash Distribution in Italian Durum Wheat Cultivars

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ABSTRACT

A new method to evaluate ash distribution patterns in durum wheat is proposed. Durum wheat samples (198) collected during two years from three locations in southern Italy were debranned by a friction debranning machine (Satake) at five successive time intervals ($level_{1,2,3,4,5}$). Ash content of debranned samples ($DAL_{1,2,3,4,5}$) and of whole kernel (WKA) was determined. Calculations indicated the percentage of ash removal (RAL) from the WKA after each debranning level. The weight of the material removed (WMR) during each debranning stage was also calculated. Statistical analysis showed the significant effect of debranning levels, years, locations, and cultivars. Differences among cultivars for ash distributions and WMR were noted. No association between DAL and WMR was found, showing that DAL could be a suitable measure of kernel ash gradient. In general, a diminishing ash trend was observed as debranning level increased. Almost all of the correlation coefficients between WKA and $DAL_{1,2,3,4,5}$ were high, both in general and for each cultivar. In general they were significant, showing DAL_1 as the most correlated.

The most simple indexes in durum wheat milling are: ash content, test weight, 1,000 kernel weight, and shrunken kernels. Several authors have shown the correlation between test weight, 1,000 kernel weight, and semolina yield (Matsuo and Dexter 1980, Barnes et al 1988). However, there is not a general agreement on the meaning of these indexes as milling yield indicators (Hook 1984). All these factors are affected by the environment. Dexter and Matsuo (1981) have shown the unfavorable effects of crop damage both on semolina yield and spaghetti quality. Milling industries in several European countries consider ash content as the most important durum wheat characteristic. In Italy, for example, a law imposes limits on ash content in durum wheat products used for human food (0.9% dmb for semolina and pasta). Studies have proved that there is a strong genotype-by-environment interaction (Cubadda 1969, Peterson et al 1986). Semolina ash content is correlated both with ash content of the whole kernel (Cubadda 1988) and with the extraction rate (Dexter and Matsuo 1978). Since the presence of a gradient in ash distribution in the kernel has been demonstrated (Morris et al 1945, Hinton 1959, Matsuo and Dexter 1980, Dexter et al 1994), it can be useful to classify commercial cultivars according to their ash distribution patterns in the kernel to improve milling yield. The objectives of this study were: 1) to develop a new and simple method for evaluating ash distribution in durum wheat kernel based upon a friction debranning machine; 2) to evaluate ash distribution pattern among cultivars; 3) to evaluate whether differences in ash distribution patterns are related to whole kernel ash content.

MATERIALS AND METHODS

Durum Wheat Samples

Eleven Italian durum wheat cultivars, including samples of old, recent, and widely cultivated cultivars (Simeto, Duilio, Trinakria, Crispiero, Tavoliere, Vespro, Fenix, Creso, Ofanto, Flavio, and Vento) were grown in three different locations in southern Italy (Cerignola, Manfredonia, and Lecce) for two years with three replicates.

Durum Wheat Debranning

Ash distribution in durum wheat kernels was obtained by dividing each plot sample of cleaned durum wheat into six 80-g subsamples. One subsample was used to determine the ash content of whole kernels, and the remaining five were debranned by friction at 1.20-, 1.40-, 2.00-, 2.20-, and 2.40-min intervals. These time intervals are referred to in text as levels 1–5 ($level_{1,2,3,4,5}$), respectively. Debranned kernel weight was recorded for each time interval. The weight of the material removed (WMR) was calculated as the difference between the initial subsample weight and its debranned weight. WMR is expressed as a percentage of the initial weight. A friction debranning machine (Satake Toshiba Corp., Tokyo) was used for debranning durum wheat kernels. It was equipped with a grinding wheel 15 cm in diameter and 3.6 cm wide (40 mesh, grade P); one high and one low expanding pulley (104 and 85 mm o.d., respectively; 1,400 rpm each); and a 0.4 kW electric motor. The evenness of each debranned subsample was noted at the end of every treatment. Debranned and whole kernel samples were milled with a Tecator Cyclotec 1093 (PBI) laboratory mill (1-mm screen).

Laboratory Analysis

Ash content was determined by standard method 08-12 (AACC 1983) on milled grain. Ash content was determined by duplicate analyses (%, w/w, dmb). Ash content of debranned samples was indicated as $DAL_{1,2,3,4,5}$ and ash content of whole kernel samples was indicated as WKA. Ash removal after each debranning level ($RAL_{1,2,3,4,5}$) was calculated as:

$$RAL = (1 - DAL/WKA) \times 100$$

Statistical Analysis

A factorial analysis of variance with hierarchical classification for locations and year was performed using the MSTAT-C program (Crop and Soil Science Department, Michigan State University). Means were compared by the least significant difference (LSD) test ($P \leq 0.01$). Correlations between WKA, WMR, and $DAL_{1,2,3,4,5}$ were performed.

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RESULTS AND DISCUSSION

Statistical analyses for ash content are reported in Table I. The largest significant effect is ascribed to debranning levels. Years, locations, and cultivars also accounted for significant effects, but with lower values. Several reports have already pointed out environmental effects (Cubadda et al 1969, Paris and Gavazzi 1972), while Peterson et al (1986) and Byrne and Rasmusson (1974) noted the genotype influence. While all the interaction effects are significant but with low values, debranning level-by-cultivar interaction is reported in this article.

Cultivar ash distribution is reported in Table II. The cultivars were divided into three groups based on WKA: group 1 contained only one cultivar, Trinakria, with the highest ash content; group 2 contained six cultivars with a medium ash content (1.91–1.93%); group 3 contained four cultivars with a low ash content (1.81–1.85%).

In general, a diminishing ash trend was observed as the debranning levels proceeded. Trinakria showed a significant diminishing trend in ash content at successive debranning levels and had a favorable ash distribution pattern in spite of its high WKA. Group 2 cultivars maintained higher ash contents than Trinakria starting from $level_2$ (DAL_2); this trend was also evident during the successive levels. Only Vespro presented an ash distribution similar to that of Trinakria. Group 3 cultivars, with low WKA values, showed less loss of ash than Trinakria as the debranning proceeded, and showed a higher ash content starting from DAL_3. This indicates that there was still a high ash content in the inner layers of the kernel. The most unfavorable ash pattern distribution, regardless of its low WKA, was found in Crispiero, as shown by high values for $DAL_{1,2,3,4,5}$.

Therefore, in this research, a new approach revealed the presence of an ash gradient in the kernel. Morris et al (1945) achieved analogous results by a microdissection technique on wheat kernels, obtaining four endosperm and two bran fractions. Hinton (1959) obtained the ash gradient by a dissection technique in accordance with the anatomical composition of wheat kernel. Matsuo and Dexter (1980) and Dexter et al (1994) showed the presence of the ash gradient by the streams of semolina produced during milling. As expected, significant differences among the WMR (%) mean values of the cultivars for each debranning level were found (Table III). But, in general, a very low significant association, or no association, was found when WMR and $DAL_{1,2,3,4,5}$ were correlated (Table IV). This means that DAL could be a suitable measure of kernel ash gradient.

RAL mean values for each debranning level and for the 11 cultivars are shown in Table III. There was a significant difference

TABLE I
Mean Squares for Factor Analysis of Variance with Hierarchical Classification for Locations in the Year for Ash Content

Source	DF	
Year (Y)	1	1.202***[a]
Location in year (L)	4	2.108***
Debranning levels (D)	5	28.650***
Y × D	5	0.017***
L × D in year	20	0.055***
Cultivars (C)	10	0.115***
Y × C	10	0.055***
L × C in year	40	0.050***
D × C	50	0.018***
Y × D × C	50	0.005
L × D × C in year	200	0.004
Error[b]	780	0.004

[a] *** = $P \leq 0.001$.
[b] Common error for all of the factors considered.

TABLE II
Average Content (% dmb) of Whole Kernel Ash (WKA) and Five Debranned Ash Levels (DAL) for 11 Cultivars

Cultivar	WKA	DAL_1	DAL_2	DAL_3	DAL_4	DAL_5
Trinakria	1.99	1.06	0.98	0.9	0.86	0.81
Ofanto	1.93	1.15	1.07	1.02	0.98	0.94
Creso	1.93	1.16	1.07	1.00	0.96	0.92
Fenix	1.92	1.12	1.02	0.94	0.89	0.86
Flavio	1.91	1.08	0.99	0.95	0.92	0.88
Vespro	1.91	1.07	0.98	0.92	0.87	0.84
Tavoliere	1.91	1.15	1.06	1.00	0.95	0.92
Vento	1.85	1.05	0.98	0.98	0.90	0.88
Crispiero	1.84	1.13	1.07	1.00	0.96	0.99
Duilio	1.83	1.07	0.99	0.94	0.91	0.88
Simeto	1.81	1.08	1.02	0.96	0.92	0.90
D × C, LSD[a]	0.05					

[a] Debranning levels (D) by Cultivar (C), least significant difference ($P \leq 0.01$).

TABLE III
Mean Values (%) of Removed Ash Level (RAL) and Weight of Material Removed (WMR) at Five Debranning Levels for 11 Cultivars

Cultivars	RAL_1	WMR_1	RAL_2	WMR_2	RAL_3	WMR_3	RAL_4	WMR_4	RAL_5	WMR_5
Trinakria	46.4	24.0	50.7	27.6	54.3	30.9	56.7	33.7	58.9	36.7
Ofanto	40.4	24.2	44.7	28.1	47.4	31.6	49.1	35.0	51.2	37.6
Creso	40.3	22.2	44.9	25.7	47.4	29.2	49.6	32.3	51.2	34.6
Fenix	41.8	21.7	46.7	25.1	51.0	28.8	53.4	31.9	55.4	34.6
Flavio	43.5	25.2	47.7	29.4	50.6	32.9	51.4	36.2	54.1	39.0
Vespro	44.2	25.7	48.7	30.0	49.3	33.1	51.2	36.5	52.6	39.3
Tavoliere	40.2	22.7	44.4	26.4	47.9	30.0	50.2	33.2	52.1	36.0
Vento	43.0	24.0	46.9	28.2	52.1	32.0	54.7	35.1	56.3	38.0
Crispiero	38.3	22.8	41.7	26.5	45.9	29.8	47.5	33.0	49.2	35.6
Duilio	41.5	24.2	45.7	28.7	48.5	32.2	50.2	35.7	52.1	38.1
Simeto	40.3	24.7	43.6	28.3	46.9	32.3	49.2	34.8	50.2	38.0
LSD[a]	2.11	1.22	2.17	1.08	2.03	1.33	1.93	1.20	1.96	1.44

[a] Least significant difference ($P \leq 0.01$).

TABLE IV
Correlation Coefficients Between Weight of Material Removed (WMR), Whole Kernel Ash (WKA), and Five Debranned Ash Levels (DAL) in General and Between WKA and DAL for 11 Cultivars

	DAL_1	DAL_2	DAL_3	DAL_4	DAL_5
WMR[a]	0.21*[c]	0.17	0.03	−0.05	−0.05
WKA[b]	0.636**	0.582**	0.542**	0.483**	0.424**
Cultivars					
Trinakria	0.220	0.338	0.158	0.216	0.043
Ofanto	0.762	0.712	0.711	0.714	0.605
Creso	0.779	0.750	0.630	0.641	0.595
Fenix	0.933**	0.923**	0.889*	0.885*	0.869*
Flavio	0.741	0.675	0.668	0.620	0.529
Vespro	0.722	0.565	0.603	0.524	0.514
Tavoliere	0.639	0.626	0.617	0.508	0.503
Vento	0.766	0.747	0.773	0.736	0.799
Crispiero	0.555	0.550	0.627	0.541	0.497
Duilio	0.797	0.783	0.740	0.680	0.579
Simeto	0.806	0.854*	0.925**	0.808	0.854*

[a] Data obtained by averaging replicates. $n = 66$.
[b] Data obtained by averaging replicates. $n = 6$.
[c] * = $P \leq 0.05$ and ** = $P \leq 0.01$.

among the cultivars. The highest value of Trinakria and the lowest of Crispiero were always preserved as the debranning level proceeded, which was already expected from the results shown in Table II. This supported the hypothesis of a relationship between RAL and DAL. Therefore, a high value of RAL, starting from $level_1$ could prove the presence of a lower ash content in the inner layers of the endosperm.

These findings on ash distribution differences among cultivars could be important for milling yield because, with the same ash content, an outer ash concentration is more desirable and allows a lower ash content in semolina. Differences among cultivars in ash concentration in the inner zone of the kernel (endosperm) were previously noted by Morris et al (1945). Correlation coefficient values between WKA and debranning parameters ($DAL_{1,2,3,4,5}$) are shown in Table IV. In general, a diminishing trend of the r value was observed, with DAL_1 showing the highest correlation. This result seemed to be in agreement with Hinton (1959), who did not find any apparent relationship between WKA and ash content in the central endosperm of 15 commercial wheat samples. Regardless of the high values of the correlation coefficients found for each cultivar, most of them were not significant (probably for the few points plotted). Only Trinakria showed the lowest or no significant correlation. This probably could explain its favorable ash pattern, which is different from the other two groups of cultivars. It is possible that only in Trinakria is the extent of the ash gradient in the endosperm really different from that of the other cultivars.

CONCLUSION

The results of this research suggest that the proposed method used to evaluate ash gradient in durum wheat is easy to perform and very effective in discriminating cultivar differences. We think breeding programs could benefit from the application of this method and from the use of RAL_1 and WKA as measures of potential durum wheat millability. In fact, RAL_1 is easily obtained and saves time, labor, and samples. Furthermore, it allows screening of lines with a favorable ash distribution pattern. A large-scale study to verify the usefulness of this method in predicting semolina milling yield has already been planned.

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