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Evaluation of Total Phenols and 3-Deoxyanthocyanidins in Sorghum Grain Using Near-Infrared (NIR) Spectroscopy

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***Abstract* – The reported phenolic levels in sorghum grain have led an interest from sorghum breeding programs in developing and identifying germplasms with phenolic compounds. The use of NIR requires screening of grain samples through calibration curves. The objectives of this research were to determine the variation range in total phenols and 3-deoxyanthocyanidins levels in a F_7 sorghum grain lines selected by tolerance to drought in the Facultad de Agronomia at the Universidad Autonoma de Nuevo Leon in Mexico, that were planted under irrigation and limited irrigation at Lubbock, Texas. Two experiments were integrated for field evaluation, each one with 20 F_7 lines, 5 parental lines and the hybrid commercial grain as a check; both were planted under irrigation and limited irrigation at flowering. The harvested seed in the two experiments let to integrate 52 treatments, one with seed from irrigation and 52 with limited irrigation seed, were statistically analyzed as a completely random experimental design. Highly significant differences were detected. From irrigation to limited irrigation the variables increased their values. Lines were identified to be useful in production for sorghum flour for high total phenols and 3-deoxyanthocyanidins concentrations in whole grain sorghum.**

***Keywords* – Sorghum, Grain, Phenolics.**

I. Introduction

Sorghum bicolor (L.) Moench originated between 4500 and 1000 BC in parts of Central Africa, subsequently spreading to Asia and India (Schober and Bean, 2008). Although the majority is grown in these areas (55%), the U.S. produces 25-30% of world production. Between 15 to 20% is grown in Latin America. S. bicolor varieties are white, red, black, yellow, brown and many shades of color depending on genetics and environmental conditions. In addition, glumes vary from tan to dark purple (Smith, 2000). Sorghum is an important food staple especially in hot, dry areas where other crops like maize fails.

This grain is used for food in India and much of sub-Saharan Africa. In the U.S., it is used as livestock feeds. It has been utilized for human consumption in porridges, beer, unleavened bread, couscous composite blends, and ethnic beverages (Taylor et al, 2006), (Waniska et al, 2004).

There has been a recent increase in the use of sorghum as a food in the United States because of its gluten-free characteristic as well as other potential health benefits which include slow digestibility, cholesterol-lowering, anticarcinogenic, and anti-inflammatory properties (Dykes and Rooney, 2006).

Utilization of sorghum in Central America is common among many rural communities that do not have access to enough cereals (i.e. corn). It is planted with maize and after the maize is harvested, the sorghum produces grain that is used in blends with maize or alone depending upon economic status. It is used in ethnic beverages (horchata, atole) and tortillas.

Sorghum has the highest content of phenolic compounds comprising of approximately 6% w/w that includes all classes of phenolic compounds such as, phenolic acids, flavonoids, antioxidants, carotenoids and condensed tannins (seeds with pigmented testa).

Hence, it is important to quantify polyphenolic contents and to assess their contribution for human nutrition. Importance of phenolics in Sorghum by protecting against stress was also reported (Dicko et al, 2006).

Nowadays, in Mexico with a project supported by CONACYT we promotes the sorghum as a food because of its gluten free characteristic, grain quality, as well as other potential health benefits which include antioxidant activity, slow digestibility, can reduce the risk of cardio-vascular disease and anticarcinogenic effects, for that reason we promoted the sorghum grain to produce flour as a human food in Mexico, mainly in the rural areas to avoid hunger and it have food security in the country.

Several methods have been used to determine sorghum phenolic levels. These include colorimetric methods [i.e. Folin–Ciocalteu, Prussian blue, ferric ammonium citrate (International Organization for Standardization), vanillin/HCl, and butanol–HCl methods], which determine relative sorghum phenolic levels among genotypes (Dykes et al, 2005). High performance liquid chromatography (HPLC) coupled with photodiode array (PDA), fluorescent, and/or mass spectroscopy (MS) detectors identify and quantify specific phenolic compounds (Chiremba et al, 2012). All aforementioned methods require sample preparation (i.e. grinding), the use of chemical solvents, technical skills, and are time-consuming. Consequently, they are not practical for screening hundreds, if not thousands, of samples in the short time required for selection in a breeding program.

To mitigate this issue, near-infrared (NIR) spectroscopy has been used to measure composition of phenolic levels in foods beverages such as rice, cocoa, and apples (Pissard et al, 2013, Whitacre et al, 2003, Zhang et al, 2008). NIR prediction is a quick, inexpensive, and non-destructive method to screen samples for desired components assuming that calibration curves can be developed that accurately relate data collected from lab-based assays to the reflectance data obtained from an NIR scan.

The Texas A&M AgriLife Research Sorghum Program has been developing such calibration curves to predict total phenols and 3-deoxyanthocyanidins levels in grain sorghum using NIR spectroscopy. The objectives of this

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study were to determine the range of variation in total phenols and 3-deoxyanthocyanidins levels in grain sorghum genotypes and to assess the predictive value of an NIR curve to estimate these compounds in sorghum grain planted under irrigation and limited irrigation.

II. Materials and Methods

Materials

A total of 52 grain sorghum samples were evaluated for total phenols and 3-deoxyanthocyanidins. For purposes of NIR calibration curve development, these were divided into calibration (33) and validation (19) sets (Table 1). These samples included grains from numerous lines and hybrids as a check and they were collected from research trials conducted in Lubbock, Texas. These samples represented the phenotypic diversity in sorghum grain appearance, which include pericarp color, the presence/absence of the pigmented testa layer and spreader gene, kernel size and shape and pericarp thickness.

Table 1. Pericarp color, tannin classifications and genes associated of sorghum samples used for the calibration and validation sets.

Calibration set		Validation set			
Pericarp color	Non-tannin sorghum	Tannin sorghum	Non-tannin sorghum	Tannin sorghum	Genes associated
Red	21	4	11	3	R_Y_
White	6	1	3	1	rryy or Rr_yy
Yellow	1	-	1	-	rr_Y_
Total	28	5	15	4	

Reference Analysis

Total phenols were measured using the Folin–Ciocalteu method of Kaluza et al, (1980). Total phenol results were expressed as mg gallic acid equivalent (GAE)/g. The 3-deoxyanthocyanidins were measured using the colorimetric method of Fuleki and Francis (1968). The absorbance of each acidified methanol extract was read at 485 nm and 3-deoxyanthocyanidins concentrations were expressed as abs/mL/g.

NIR Scanning

NIR spectra were obtained using a FOSS XDS NIR spectrometer (FOSS North America, Eden Prairie, MN, USA). Each whole grain sample was packed (2.54 cm deep) into a rectangular-shaped sample cup (15.24 cm × 3.81 cm × 5.08 cm, length × width, depth) and was scanned twice using the wavelength range of 400–2500 nm. Collection of the spectra data was done using the ISI scan software (Version 3.10.05933) set at 32 readings per scan and stored at 2 nm intervals. The average of two scans was used for the equation development. The calibration model was developed using the Win ISI software (version 4.0.03770) that supports the modified partial leastsquares (mPLS) method which creates a calibration equation for each of the variables separately. In the development process, several equations were tested which varied in derivative math treatment.

Accuracy, precision, and robustness of the method were determined using 19 samples in a validation set (Table 1). Like the samples used for the calibration set, samples varied based on pericarp color, presence of a pigmented testa and spreader gene and pericarp thickness. Scanning and analysis were as previously described.

III. Results and Discussion

Certain specialty sorghum genotypes have been identified as potential whole grain foods that have high levels of desired chemical compounds. Specifically, sorghums with a pigmented pericarp are excellent sources of antioxidant compounds, including the unique compound 3-deoxyanthocyanidins. Our evaluations are helpful for the sorghum breeders in selection of genotypes as parents with good biochemical profile.

Various types of sorghum have grain with phytochemicals that can impart health benefits when consumed (Awika and Rooney, 2004). Specifically, flavonoids concentrated in the outer layers of the pericarp contain anti-cancer and antiinflammatory characteristics when consumed. Three groups of flavonoids exist in varies different sorghum genotypes; 3-deoxyanthocyanidins, flavones and flavanones. The concentrations of these beneficial compounds vary greatly between genotype and are influenced by environmental factors such as light, temperature, and fungal infection (Dykes et al, 2009).

Also, studies on sorghum shown that it has antioxidant activity, anti-carcinogenic effects and can reduce the risk of cardio-vascular diseases.

In the Table 2 for total phenols in sorghum, shows that the line LES154 with 9.9 mg/g under irrigation and the line 1823x154-1-6-6-1pl-1⊗ with 13.6 mg/g under limited irrigation present the highest total phenols content, we can see that the line derived from the cross where participated LES 154 inherited a high production potential of total phenols, so this line to also have a good agronomic potential and acceptable grain yield under irrigation and limited irrigation in previous studies (Flores-Naveda et al, 2012), (Flores-Naveda et al, 2013), can be considered as parent lines to produce high total phenols content in sorghum grain.

The F_7 lines derived from crosses 1823 A x 154 R, 1829 A x 151 R presented acceptable average values of 9.2 to 8.4 mg/g for total phenol content in the grain, these values are similar to the average values reported by (Dykes et al, 2014) 8.28 mg/g for total phenols in lines and sorghum hybrids from research trials of Texas A & M in Weslaco, Corpus Christi, College Station and Halfway in Texas Table 2. Meanwhile, (Sene et al, 2001) reported that nutrition with nitrogen promotes plant growth, grain yield and the synthesis of phenols in grain sorghum improvement. Total phenol levels differ significantly between different types of sorghum with high levels of tannins.

The color of the sorghum plant affects the total phenols content, the red color in sorghum grain, color purple plant and thick pericarp had high total phenolic content. In the present study the line 1823x154-1-6-6-1pl-1⊗ presented 13.6 mg/g under limited irrigation, this line has a red testa and a color purple plant, this coincides with the results

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reported by (Beta et al, 1999), who found a positive relationship between total phenolic content in sorghum plants with these agronomic characteristics.

For 3-deoxyanthocyanidins Table 3, the values range from 25.9 to 047 abs/mL/g and 43.6 to 12.4 abs/mL/g under irrigation and limited irrigation respectively, showing that under conditions of water stress the sorghum grain sorghum it increases anthocyanin content.

The line had the highest content of 3-deoxyanthocyanidins was 398x10351-1-2-5-1⊗-1⊗ with 25.9 abs/mL/g, under irrigation and under limited irrigation, 398x150-3-4-5- 2⊗-1⊗ with 43.6 abs/mL/g, both lines are color red testa and color purple plant, as this coincides point (Beta et al, 1999) that found a positive relationship between total phenols content and anthocyanins and sorghum plants with these agronomic traits.

Sorghums with a pigmented testa had high levels of 3-deoxyanthocyanidins (Awika and Rooney, 2004), (Rooney and Awika, 2005), (Dykes et al, 2005). The results reported in this study are consistent with the values reported by (Dykes et al, 2014) for average content of 39.62 abs/mL/g of 3-deoxyanthocyanidins in sorghum, although a high content of 43.6 abs/mL/g is reported for line derived from the cross 398x150-3-4-5-2⊗-1⊗ under limited irrigation. Therefore, the presence of 3-deoxyanthocyanidins evaluated in sorghum genotypes presents a potential health benefit as they exhibit antioxidant effects. The results obtained by calibration curves with NIR spectroscopy showed good potential for estimating the concentrations of the variables evaluated in the whole grain sorghum.

Sorghum with a pigmented testa has high levels of phenolic compounds, especially 3-deoxyanthocyanidins, which have application in food science and human nutrition as a high-antioxidant food additive, natural food colorant and natural food preservative.

Table 2: Means and DMS P≤0.05 in 52 grain sorghum samples, treatments (T) for total phenols under irrigation (TPI) and total phenols under limited irrigation (TPLI) in (mg GAE/g). These samples were collected from research trials conducted in Lubbock, Texas.

T	Genotipo	TPI	T	Genotipo	TPLI	T	Genotipo	TPI	T	Genotipo	TPLI
49	LES 154	9.9	12	1823x154-1-6-6-1pl-1⊗	13.6	17	1823x154-4-5-5-2pl-1⊗	7.5	21	LES 398 B	9.5
48	1829 B	9.8	13	1823x154-4-5-3-1⊗-1⊗	12.3	34	1829x151-5-3-(11)-6-1pl-4⊗	7.5	15	1823x154-4-5-5-1⊗-2⊗	9.4
24	LES 154	9.2	2	398x10351-1-2-5-1⊗-1⊗	12.1	47	1823 B	7.5	34	1829x151-5-3-(11)-6-1pl-4⊗	9.4
28	1823x154-4-5-6-2⊗-3⊗	9.2	8	398x151-7-5-1-1⊗-1⊗	12.1	12	1823x154-1-6-6-1pl-1⊗	7.4	27	1823x154-4-5-6-2⊗-1⊗	9.3
29	1829x151-5-7-4-1⊗-2⊗	9.2	5	398x151-5-3-6-1⊗-1⊗	11.7	14	1823x154-4-5-5-1⊗-1⊗	7.4	38	1829x10351-1-2-4-1⊗-1⊗*	9.0
30	1829x151-5-7-4-2⊗-1⊗	9.2	4	398x150-3-4-5-2⊗-1⊗	11.4	5	398x151-5-3-6-1⊗-1⊗	7.3	32	1829x151-5-3-(11)-6-1pl-1⊗	8.9
31	1829x151-5-7-4-2⊗-2⊗	8.9	23	LES 151	11.3	6	398x151-5-3-6-1⊗-2⊗	7.3	33	1829x151-5-3-(11)-6-1pl-2⊗	8.8
13	1823x154-4-5-3-1⊗-1⊗	8.8	16	1823x154-4-5-5-1pl-2⊗	11.2	18	1823x154-4-5-5-2pl-2⊗	7.3	50	LES 151	8.6
35	1829x151-5-3-(12)-3-1pl-1⊗	8.6	24	LES 154	11.2	21	LES 398B	7.3	9	398x151-7-5-4-1⊗-2⊗	8.4
36	1829x151-5-4-(12)-3-1pl-2⊗	8.5	29	1829x151-5-7-4-1⊗-2⊗	11.2	20	1823x154-4-5-5-2pl-4⊗	7.2	10	398x151-7-5-11-2⊗-1⊗	8.2
37	1829x151-5-4-(12)-3-1⊗-1⊗	8.5	31	1829x151-5-7-4-2⊗-2⊗	11.0	4	398x150-3-4-5-2⊗-1⊗	7.1	48	1829 B	8.2
15	1823x154-4-5-5-1⊗-2⊗	8.4	6	398x151-5-3-6-1⊗-2⊗	10.9	38	1829x10351-1-2-4-1⊗-1⊗*	5.7	11	1823x154-1-6-4-2pl-1⊗	8.1
23	LES 151	8.4	1	398x10351-1-1-2-5-1⊗	10.7	39	1829x10351-2-1-3-1⊗-1⊗	5.6	40	1829x10351-1-1-1-2pl-1⊗	8.1
11	1823x154-1-6-4-2pl-1⊗	8.2	36	1829x151-5-4-(12)-3-1pl-2⊗	10.6	52	84G11	5.4	47	1823 B	7.8
2	398x10351-1-2-5-1⊗-1⊗	8.1	37	1829x151-5-4-(12)-3-1⊗1⊗	10.5	40	1829x10351-1-1-1-2pl-1⊗	5.3	26	1823 B	7.4
1	398x10351-1-1-2-5-1⊗	8.0	30	1829x151-5-7-4-2⊗-1⊗	10.5	42	WM3845-4-6-24-4-1⊗-1⊗	5.1	42	WM3845-4-6-24-4-1⊗-1⊗	7.3
8	398x151-7-5-1-1⊗-1⊗	8.0	7	398x151-5-3-6-1⊗-3⊗	10.4	26	1823 B	5.0	44	WM3845-3-3-12-1⊗-1⊗	7.0
3	398x150-3-4-3-1⊗-1⊗	7.9	14	1823x154-4-5-5-1⊗-1⊗	10.2	50	LES 151	4.8	51	LES 10351	6.9
19	1823x154-4-5-5-2pl-3⊗	7.9	18	1823x154-4-5-5-2pl-2⊗	10.2	22	LES 10351	4.6	25	84G11	6.8
33	1829x151-5-3-(11)-6-1pl-2⊗	7.9	28	1823x154-4-5-6-2⊗-3⊗	10.0	51	LES 10351	4.6	41	WM3845-3-3-4-1⊗-1⊗	6.4
16	1823x154-4-5-5-1pl-2⊗	7.8	19	1823x154-4-5-5-2pl-3⊗	9.9	45	WM3845-4-3-13-5-3⊗-1⊗	4.4	46	WM3845-4-6-24-6-2⊗-1⊗	6.4

32	1829x151-5-3-(11)-6-1pl-1⊗	7.8	3	398x150-3-4-3-1⊗-1⊗	9.7	25	84G11	4.2	22	LES 10351	5.6
7	398x151-5-3-6-1⊗-3⊗	7.7	49	LES 154	9.7	41	WM3845-3-3-4-1⊗-1⊗	3.9	52	84G11	5.4
10	398x151-7-5-11-2⊗-1⊗	7.7	20	1823x154-4-5-5-2pl-4⊗	9.6	43	WM3845-7-5-12-2pl-1⊗	3.8	45	WM3845-4-3-13-5-3⊗-1⊗	5.3
27	1823x154-4-5-6-2⊗-1⊗	7.6	35	1829x151-5-3-(12)-3-1pl-1⊗	9.6	46	WM3845-4-6-24-6-2⊗-1⊗	3.5	39	1829x10351-2-1-3-1⊗-1⊗	5.1
9	398x151-7-5-4-1⊗-2⊗	7.5	17	1823x154-4-5-5-2pl-1⊗	9.5	44	WM3845-3-3-12-1⊗-1⊗	3.2	43	WM3845-7-5-12-2pl-1⊗	5.0
							DMS P≤0.05	0.96		DMS P≤0.05	0.67

Table 3: Means and DMS P≤0.05 in 52 grain sorghum samples, treatments (T) for 3-deoxyanthocyanidins concentrations under irrigation (3-DI) and 3-deoxyanthocyanidins under limited irrigation (3-DLI) in (abs/mL/g). These samples were collected from research trials conducted in Lubbock, Texas.

T	Genotipo	3-DI	T	Genotipo	3-D LI	T	Genotipo	3-DI	T	Genotipo	3-D LI
2	398x10351-1-2-5-1⊗-1⊗	25.9	4	398x150-3-4-5-2⊗-1⊗	43.6	16	1823x154-4-5-5-1pl-2⊗	7.0	25	84G11	23.6
48	1829 B	24.2	2	398x10351-1-2-5-1⊗-1⊗	42.8	18	1823x154-4-5-5-2pl-2⊗	6.8	14	1823x154-4-5-5-1⊗-1⊗	23.2
7	398x151-5-3-6-1⊗-3⊗	21.6	5	398x151-5-3-6-1⊗-1⊗	42.5	26	1823 B	6.8	44	WM3845-3-3-12-1⊗-1⊗	23.0
1	398x10351-1-1-2-5-1⊗	21.3	12	1823x154-1-6-6-1pl-1⊗	39.2	9	398x151-7-5-4-1⊗-2⊗	6.6	34	1829x151-5-3-(11)-6-1pl-4⊗	22.4
11	1823x154-1-6-4-2pl-1⊗	21.2	31	1829x151-5-7-4-2⊗-2⊗	35.5	42	WM3845-4-6-24-4-1⊗-1⊗	6.2	36	1829x151-5-4-(12)-3-1pl-2⊗	22.4
49	LES 154	20.6	1	398x10351-1-1-2-5-1⊗	34.6	37	1829x151-5-4-(12)-3-1⊗-1⊗	5.6	35	1829x151-5-3-(12)-3-1pl-1⊗	22.3
30	1829x151-5-7-4-2⊗-1⊗	19.8	3	398x150-3-4-3-1⊗-1⊗	34.3	20	1823x154-4-5-5-2pl-4⊗	5.6	47	1823 B	22.2
31	1829x151-5-7-4-2⊗-2⊗	18.5	7	398x151-5-3-6-1⊗-3⊗	33.9	51	LES 10351	5.6	20	1823x154-4-5-5-2pl-4⊗	21.7
5	398x151-5-3-6-1⊗-1⊗	18.4	30	1829x151-5-7-4-2⊗-1⊗	33.6	6	398x151-5-3-6-1⊗-2⊗	5.3	17	1823x154-4-5-5-2pl-1⊗	21.6
24	LES 154	18.1	13	1823x154-4-5-3-1⊗-1⊗	33.2	38	1829x10351-1-2-4-1⊗-1⊗*	5.1	42	WM3845-4-6-24-4-1⊗-1⊗	21.0
23	LES 151	15.8	8	398x151-7-5-1-1⊗-1⊗	33.0	33	1829x151-5-3-(11)-6-1pl-2⊗	4.5	19	1823x154-4-5-5-2pl-3⊗	20.4
3	398x150-3-4-3-1⊗-1⊗	14.6	6	398x151-5-3-6-1⊗-2⊗	31.3	10	398x151-7-5-11-2⊗-1⊗	4.4	41	WM3845-3-3-4-1⊗-1⊗	20.6
21	LES 398B	14.5	21	LES 398 B	30.5	39	1829x10351-2-1-3-1⊗-1⊗	4.3	32	1829x151-5-3-(11)-6-1pl-1⊗	19.2
35	1829x151-5-3-(12)-3-1pl-1⊗	14.2	29	1829x151-5-7-4-1⊗-2⊗	28.6	52	84G11	4.3	33	1829x151-5-3-(11)-6-1pl-2⊗	19.1
29	1829x151-5-7-4-1⊗-2⊗	14.0	16	1823x154-4-5-5-1pl-2⊗	28.4	19	1823x154-4-5-5-2pl-3⊗	4.1	26	1823 B	19.0
4	398x150-3-4-5-2⊗-1⊗	14.0	24	LES 154	28.2	50	LES 151	3.9	50	LES 151	18.6
13	1823x154-4-5-3-1⊗-1⊗	13.6	23	LES 151	28.0	14	1823x154-4-5-5-1⊗-1⊗	3.6	9	398x151-7-5-4-1⊗-2⊗	18.5
40	1829x10351-1-1-1-2pl-1⊗	12.4	11	1823x154-1-6-4-2pl-1⊗	27.4	25	84G11	3.2	15	1823x154-4-5-5-1⊗-2⊗	18.1
28	1823x154-4-5-6-2⊗-3⊗	12.0	48	1829 B	24.8	15	1823x154-4-5-5-1⊗-2⊗	3.0	46	WM3845-4-6-24-6-2⊗-1⊗	17.9
12	1823x154-1-6-6-1pl-1⊗	11.2	37	1829x151-5-4-(12)-3-1⊗1⊗	24.5	41	WM3845-3-3-4-1⊗-1⊗	2.7	38	1829x10351-1-2-4-1⊗-1⊗*	17.3
27	1823x154-4-5-6-2⊗-1⊗	9.9	51	LES 10351	24.4	32	1829x151-5-3-(11)-6-1pl-1⊗	2.6	52	84G11	17.0
36	1829x151-5-4-(12)-3-1pl-2⊗	9.4	28	1823x154-4-5-6-2⊗-3⊗	24.3	46	WM3845-4-6-24-6-2⊗-1⊗	1.3	10	398x151-7-5-11-2⊗-1⊗	16.6
8	398x151-7-5-1-1⊗-1⊗	8.7	40	1829x10351-1-1-1-2pl-1⊗	24.3	22	LES 10351	1.0	22	LES 10351	16.2
47	1823 B	8.6	18	1823x154-4-5-5-2pl-2⊗	24.1	43	WM3845-7-5-12-2pl-1⊗	1.0	39	1829x10351-2-1-3-1⊗-1⊗	15.4

17	1823x154-4-5-5-2pl-1⊗	7.6	49	LES 154	24.0	45	WM3845-4-3-13-5-3⊗-1⊗	.566	45	WM3845-4-3-13-5-3⊗-1⊗	12.8
34	1829x151-5-3-(11)-6-1pl-4⊗	7.3	27	1823x154-4-5-6-2⊗-1⊗	24.0	44	WM3845-3-3-12-1⊗-1⊗	.047	43	WM3845-7-5-12-2pl-1⊗	12.4
							DMS P≤0.05	2.73		DMS P≤0.05	2.48

IV. Conclusion

The resultant calibration curves indicate that NIR spectroscopy has good potential to predict total phenol and 3-deoxyanthocyanidin concentrations in whole grain sorghum. This method has many advantages over the conventional methods (colorimetric assays, HPLC) because it is quick, inexpensive, non-destructive, and does not require the use of chemical solvents.

In sorghum breeding program estimate the grain quality by NIR can be used effectively for rapid screening to eliminate those that do not possess the trait of interest. Finally, this method will benefit plant breeders to rapidly screen sorghums for high levels of health promoting components to produce sorghum flour as a human food in Mexico.

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References

[1] Awika J. M, Rooney L. W. 2004. Sorghum phytochemicals and their potential impact on human health. Phytochemistry 65; 1199-1221. 2004.

[2] Beta T, Rooney L.W., Marobatsanga L.T., Taylor, J.R.N. 1999. Phenolic compounds and kernel characteristics of Zimbabwean sorghums. J. Sci. Food Agric. 79. 1003-1010.

[3] Chiremba, C., Taylor, J.R.N., Rooney, L.W., Beta, T., 2012. Phenolic acid content of sorghum and maize cultivars varying in hardness. Food Chem. 134, 81–88.

[4] Dicko, M. H., Gruppen. H., Zouzouho, O. C., Traore, A. S., Van Berkel, W. J. H. and Voragen, A. G. J. (2006): Effects of germination on the activities of amylases and phenolic enzymes in sorghum varieties grouped according to endues properties. Journal of Agriculture and Food Chemistry, 50: 3780-3788.

[5] Dykes, L., Rooney, L.W., Waniska, R.D., Rooney, W.L., 2005. Phenolic compounds and antioxidant activity of sorghum grains of varying genotypes. J. Agric. Food Chem. 53, 6813–6818.

[6] Dykes, L., Rooney, L.W., 2006. Sorghum and millet phenols and antioxidants. J. Cereal Sci. 44, 236–251.

[7] Dykes, L., Seitz, L., Rooney, W.L., Rooney, L.W., 2009. Flavonoid composition of red sorghum genotypes. Food Chem.116, 313–317.

[8] Dykes, L., Hoffmann L, Portillo-Rodriguez O, Rooney W. L, Rooney L. W. 2014. Prediction of total phenols, condensed tannins and 3-deoxyanthocyanidins in sorghum grain using near-infrared (NIR) spectroscopy. INTSORMIL. Scientific Publications. Paper 44.

[9] Flores-Naveda, A., Valdes L.C.G.S, Rooney W. L, Olivares S. E, Zavala G. F, Gutierrez D. A, Vazquez B. M. E. 2012. Grain yield of sorghum lines planted under irrigation and limited irrigation in Texas. International Journal of Experimental Botany. (2012) 81: 113-121.

[10] Flores-Naveda, A., Valdes L.C.G.S, Zavala G. F, Olivares S. E, Gutierrez D. A, Vazquez B. M. E. 2013. Agronomic performance of sorghum seed production lines. Agronomia Mesoamericana. 24 (1): 111-118.

[11] Fuleki, T., Francis, F.J., 1968. Quantitative methods for anthocyanins.1. Extraction and determination of total anthocyanin in cranberries. J. Food Sci. 33, 72–77.

[12] Kaluza, W.Z., McGrath, R.M., Roberts, T.C., Schroder, H.H., 1980. Separation of phenolics of Sorghum bicolor (L.) Moench grain. J. Agric. Food Chem. 28, 1191–1196.

[13] Pissard, A., Pierna, J.A.F., Baeten, V., Sinnaeve, G., Lognay, G., Mou- teau, A., Dupont, P., Rondia, A., Lateur, M., 2013. Nondestructive measurement of vitamin C, total polyphenol and sugar content in apples using near-infrared spectroscopy. J. Sci. Food Agric. 93, 238–244.

[14] Rooney L.W. and Awika, J.M. 2005. Specialty sorghums for healthful foods. In specialty grains for food and feed. First ed., A.E., Wood P, Eds. American Association of Cereal Chemists, Inc. St. Paul, MN. USA. pp 283-312.

[15] Schober, T. J. and Bean, S. R. 2008. Sorghum and maize. Pages 101-118 in: Gluten-Free Cereal Products and Beverages. K. A. Elke and B. Fabio Dal, eds. Academic Press: San Diego, CA.

[16] Sene, M, Dore, T, and Gallet, C. 2001. Relationship between biomass and phenolic production in grain sorghum grown under different conditions. Agronomy Journal. 93 (1) 49-54.

[17] Smith, C. W. 2000. Sorghum Production Statistics. Page 7 in: Sorghum: Origin, history, technology and production. C. W. Smith, ed. John Wiley and Sons: New York.

[18] Taylor, J. R. N., Schober, T. J. and Bean, S. R. 2006. Novel food and non-food uses for sorghum and millets. J. Cereal Sci. 44:252-271.

[19] Waniska, R. D., Rooney, L. W. and McDonough, C. M. 2004. Sorghum: Utilization. Pages 126-136 in: Encyclopedia of Grain Science. W. Colin, ed. Elsevier: Oxford

[20] Whitacre, E., Oliver, J., van den Broek, R., van Engelen, P., Kremers, B., van der Horst, B., Stewart, M., Jansen-Beuvink, A., 2003. Predictive analysis of cocoa procyanidins using near-infrared spectroscopy techniques. J. Food Sci. 68, 2618–2622.

[21] Zhang, C., Shen, Y., Chen, J., Peng, X., Bao, J., 2008. Nondestructive prediction of total phenolics, flavonoid contents, and antioxidant capacity of rice grain using near-infrared spectroscopy. J. Agric. Food Chem. 56, 8268–8272.

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