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Sugars in Whole Sesame Seed: Effects of Cultivars, Planting Dates and Row Spacings

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Authors' contributions

This work was carried out in collaboration between all authors. Author HLB designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author AAH conducted the chemical analysis. Author MEK helped with field production. Author DRL provided seeds and basic information about sesame. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Mean contents of fructose, glucose, raffinose, stachyose, sucrose, and total sugars in whole sesame seed, produced during 2011 and 2012 in mid-Atlantic region of the United States of America, were 0.95, 1.28, 2.22, 0.14, 0.82, and 5.39 g/100g meal, respectively. Planting time effects were significant for contents of fructose, glucose, raffinose, stachyose, sucrose, and total sugars. Contents of sucrose and total sugars were highest during both plantings in 2011 as compared to those for both planting dates in 2012. However, differences between two planting dates for total sugar contents during each year were not significant while earlier plantings in both years had significantly higher contents of sucrose. Raffinose content was significantly greater from late planting during 2011 over early planting whereas planting date effects during 2012 were not different. Stachyose content was significantly greater from early planting in 2012 over late planting whereas planting date effects during 2011 were not significant. An increase in row spacing from 37.5cm to 75cm increased the content of fructose by 24.7% but resulted in 8.1% decrease in content of glucose. Cultivar effects were significant only for sucrose. S26 and S32 cultivars had significantly higher content over that of 22K (0.89, 0.89, and 0.69g/100g meal, respectively). These results indicate that sugar contents in sesame whole seed

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could be manipulated by using specific growing conditions and cultivars and could be helpful in determination of sugar intake via consumption of whole seeds.

Keywords: Sesamum indicum L.; total sugar content; fructose content; glucose content; sucrose content; raffinose content; stachyose content.

1. INTRODUCTION

This study was conducted to determine if sesame (*Sesamum indicum* L., Pedaliaceae) could be produced in a non-traditional area to diversify cropping system and to characterize composition of sesame related to human nutrition. Sesame is one of the oldest crops known to humans. Through the ages, sesame seeds have been a source of food and oil. About 65% of the annual sesame crop is processed into oil and 35% is used in food [1]. International demand for sesame continues to increase every year. The world's traded sesame seed recently surpassed one million tons per year and was valued at approximately $850 million. In the last 15 years, world trade in sesame has increased by nearly 80%. The United States imports more sesame than it grows. In 2010, the United States imported sesame seed valued at $69.9 million which was relatively unchanged from 2009 [1]. This observation indicates that there is potential for enhancing sesame production in the United States. Due to significant reductions in tobacco (*Nicotiana tabacum* L.) and peanut (*Arachis hypogea* L.) acreage in Virginia in recent times, the New Crops Program of Virginia State University has been evaluating several summer crops that can be grown in Virginia to help agricultural diversification and to enhance farm incomes. In this regard, sesame is considered a potentially lucrative crop. There is a complete lack of information about sesame production in this region and additionally regarding composition of sesame seed produced in this region.

It is well established that foods determine human health. Given that all foods originate from plants, it is imperative that composition of plant products, to be used as foods, be clearly known so that informed decisions could be made regarding human nutrition. Diabetes and obesity are two of the most critical health issues in the United States today, with millions of dollars poured into research every year to further uncover the sources of this epidemic in order to cure/manage this disease. Researchers at the Yale School of Medicine have uncovered a feed-forward mechanism whereby excess sugar consumption may lead to increased fat production in the liver and the ensuing development of diabetes [2]. Although there is a lack of dietary trials linking sugar consumption with human diseases, it is commonly suggested that sugar consumption should be limited [3,4,5,6].

One objective of our research was to determine if sesame could be successfully produced in Virginia. Additionally, we were interested in characterization of sugars in sesame seed produced in the mid-Atlantic region of the United States of America to address issues related to management of diabetes.

2. MATERIALS AND METHODS

2.1 Plant Material and Production

Five proprietary sesame cultivars (22K, S26, S28, S30, and S32) from Sesaco Corporation (San Antonio, Texas, USA) were used in this study. This field study was conducted at

Randolph Farm of Virginia State University located in Ettrick, Virginia. These cultivars were planted in four-row plots with row spacings of 37.5 and 75cm in an Abel Sandy Loam soil. Sesame was planted on May 23 and June 8 during 2011 and on July 9 and July 17 during 2012 using a split-plot experimental design with planting dates as main plots, row spacings as sub-plots and cultivars as sub-sub-plots with four replications of a Randomized Complete Block Design. The soil received a pre-plant incorporated application of approximately 2 liters of trifluralin herbicide per hectare. Seeding rate for this study was approximately 3kg/ha, the plot length was 3 m and the seed was planted on a flat bed. Seeding was accomplished using a four-row research planter. The experimental area did not receive any irrigation. The experimental area received a fertilizer application of 112kg per hectare each of N, P, and K. All plots were harvested manually at maturity, generally in November to December of each year.

2.2 Determination of Contents of Fructose, Glucose, Sucrose, Total Sugars, Raffinose, and Stachyose Contents in Whole Sesame Seeds

Fructose, glucose, sucrose, raffinose, stachyose and total sugars in whole sesame seeds were extracted from defatted ground sample and analyzed by high-performance liquid chromatograph (HPLC) following the methods optimized by Johansen et al. [7]. Triplicate of 1.0g of the defatted sample was placed in 25mL centrifuge tube and suspended in 2mL of 99% (v/v) ethanol then heated in a boiling water bath for 5 min. The sample was placed in the fume hood until all ethanol had evaporated. Sugars were then extracted from the defatted sample with 10mL of deionized water containing 5 mg trehalose internal standard at room temperature in a horizontal shaker at 200 rpm for 60 minutes. The suspension was then centrifuged at 13000rpm for 10 minutes, and 500µL of the clear supernatant was filtered through a syringe nylon membrane filter (25mm diameter, 0.2µm; Waters Associates, Inc., Milford, MA USA). An aliquot of 20µL of the filtered sugars extract were auto-injected into a Waters Alliance 2695-HPLC System equipped with Waters refractive index detector (Waters 2414 RID - Waters Associates, Inc., Milford, MA USA). The separation of fructose, glucose, sucrose, raffinose, and stachyose was achieved using a Prevail carbohydrate column ES 5µm (250x4.6mm), preceded by a Prevail carbohydrate ES guard column 53mmx7.0mm (Grace, Deerfield, IL USA). Column, sample and detector temperature were maintained, respectively, at 50, 25, 30℃. The mobile phase, acetonitrile/water (75:25 v/v), was run isocratically at a flow rate of 1.0mL/min, and the elution was monitored by Waters 2414 RID. Sugars in the extracts were identified by comparing their retention times with standard sugars. Quantification of fructose, glucose, sucrose, raffinose, and stachyose in the sample was done by comparing the area of the peaks of the respective sugars in the sample chromatogram with that of the trehalose internal standard using Empower II software (Waters Associates, Inc., Milford, MA USA). The concentrations of fructose, glucose, sucrose, raffinose, and stachyose were expressed as g/100g oil-free meal.

2.3 Statistical Analysis

All data were analyzed using the Analysis of Variance procedures in version 9.3 of SAS [8]. Effects of cultivars and row spacings were analyzed by combining data from both years. However, four planting dates were analyzed separately. The means were compared using Fisher's Protected Least Significant Difference at a 5% level of significance.

3. RESULTS AND DISCUSSION

Analysis of variance (Table 1) indicated that planting dates significantly affected contents of fructose, glucose, sucrose, raffinose, stachyose, and total sugars; row spacings significantly affected contents of fructose and glucose; and cultivars significantly affected only the content of sucrose in whole sesame seeds.

Table 1. Partial analysis of variance (Mean squares) for contents of sugars in seeds of five sesame cultivars grown using two planting dates and two row spacings in Virginia during 2011 and 2012

Trait/Source	Fructose^x	Glucose^x	Sucrose^x	Raffinos^x	Stachyoe^x	Total sugars^x
Planting dates(PD)	**	**	**	**	**	**
Row spacings (RS)	*	**	ns	ns	ns	ns
Cultivars(C)	ns	*	*	ns	ns	ns
PDxRS	**	**	ns	*	**	**
PDxC	ns	ns	ns	ns	*	ns
RSxC	ns	ns	ns	ns	ns	ns
PDxRSxC	ns	ns	ns	ns	ns	ns
Mean	0.95	1.28	0.82	2.22	0.14	5.39

**, ** : Mean squares significantly different from residual mean squares at 5 and 1% levels, respectively when tested against appropriate error mean squares as per split-plot analysis. x :Sugar contents as g/100 g meal*

Planting date effects on contents of various sugars were not consistent. Earlier planting during both years resulted in increased contents of sucrose (25% increase during 2011 and 57% increase during 2012). Early planting resulted in significantly decreased content of raffinose during 2011 but increased the content of stachyose during 2012 (Table 2). Increasing the spacing between rows from 37.5cm to 75cm resulted (Table 3) in a 24.7% increase in fructose content (1.06 and 0.85g/100g meal, respectively) and caused an 8.1% decrease in glucose content (1.33 and 1.23g/100g meal, respectively). Differences among five sesame cultivars were generally not significant for most sugars (Table 4). Content of sucrose in S26 and S32 cultivars were significantly higher as compared to 22K cultivar (0.89, 0.89, and 0.69g/100g meal, respectively).

Table 2.Effects of planting dates on contents of sugars in seeds of five sesame cultivars grown using two row spacings in Virginia during 2011 and 2012

Planting date/Trait	May 23, 2011	June 8, 2011	July 9, 2012	July 17, 2012
Fructose^x	1.73 a	1.56 a	0.30 b	0.22 b
Glucose^x	0.97 c	1.23 b	1.29 b	1.63 a
Sucrose^x	1.19 a	0.95 b	0.69 c	0.44 d
Total sugars^x	6.30 a	6.65 a	4.28 b	4.31 b
Raffinose^x	2.34 b	2.88 a	1.82 c	1.85 c
Stachyose^x	0.08 b	0.11 b	0.26 a	0.08 b

x: Sugar contents as g/100 g meal. : Mean within rows followed by similar letters were not different according to LSD at 5% level*

Use of a limited number of cultivars in this study may have resulted in limited effects on contents of various sugars in whole sesame seed. However, most of the worldwide sesame production is based on use of traditional cultivars that are tall and are shattering types [9]. Shattering of sesame capsules in traditional cultivars is not conducive to mechanical harvesting. Sesaco, a private company based in Texas (USA), has been breeding sesame to develop dwarf and shatter-resistant sesame cultivars for several years and released the first dwarf and shatter-resistant sesame cultivar in 1982 [9]. In 2010, Sesaco had more than 100,000 acres of sesame under contract production with growers in southwest Kansas, Oklahoma and central Texas. All dwarf and shatter-resistant sesame cultivars from Sesaco are proprietary. We expect that inclusion of a wider number of sesame cultivars in studies like this would indicate an expanded range of sugar contents.

Table 3. Row spacing effects on contents of sugars in seeds of five sesame cultivars produced using two planting dates in Virginia during 2011 and 2012

Variable	37.5 cm	75 cm
Fructose^x	0.85b*	1.06a
Glucose^x	1.33a	1.23b
Sucrose^x	0.84a	0.79a
Total sugars^x	5.37a	5.40a
Raffinose^x	2.27a	2.18a
Stachyose^x	0.13a	0.14a

x: Sugar contents as g/100 g meal. : Mean within rows followed by similar letters were not different according to LSD at 5% level*

Table 4 .Cultivar differences for contents of sugars in seeds of sesame produced using two row spacings and two planting dates in Virginia during 2011 and 2012

Variable	22K	S26	S28	S30	S32
Fructose^x	1.12a*	0.87a	0.96a	0.96a	0.85a
Glucose^x	1.24a	1.42a	1.30a	1.28a	1.16a
Sucrose^x	0.69b	0.89a	0.81ab	0.81ab	0.89a
Total sugars^x	5.39a	5.58a	5.54a	5.28a	5.14a
Raffinose^x	2.21a	2.28a	2.36a	2.13a	2.14a
Stachyose^x	0.13a	0.12a	0.11a	0.16a	0.17a

x: Sugar contents as g/100 g meal. : Mean within rows followed by similar letters were not different according to LSD at 5% level*

Our results indicated that early planting resulted in increased contents of fructose, sucrose, and stachyose in whole sesame seed. However, contents of glucose, total sugars and raffinose were not affected by planting date indicating that sesame can be produced in Virginia by using either early or late planting dates. However, early planting is expected to produce sesame seeds that are sweeter over those produced by planting late. The sesame consumption is not directly related to diabetes. However, consumers and others need to be made aware that sesame seed does contain sugar and could be an issue if one is diabetic or if one is concerned about sugar intake. Our focus was on the finding that sugar content in sesame seed varies with growing conditions and the varieties used. Raffinose and Stachyose are considered non-nutritive and are not completely digested by human beings [10]. In recent times, non-nutritive carbohydrates in food grains are receiving increasing attention due to their limited digestibility and potential use in obesity reduction efforts [11].

With regards to identifying an optimal row spacing for sesame production in Virginia, relative to sugar content of whole sesame seed, our results indicate that based on contents of all sugars other than fructose and glucose, either a closer row spacing (37.5cm between rows) or a wider row spacing (75cm between rows) could be used. Our objectives were to identify optimal row spacing for sesame production in Virginia because farmers, generally, resist purchase of new equipment when initially evaluating production of new, non-traditional crops. Most Virginia farmers own soybean planters either configured for 37.5cm or 75cm rows, therefore, sesame in Virginia could be planted with existing planters. Given that amount of seed for planting is small, it might be desirable to use 37.5 cm rows because of weed control due to shading. On the other hand, if sesame is to be produced organically via cultivation than 75cm rows might be desirable.

4. CONCLUSIONS

Results of our study indicated that planting times affect contents of fructose, glucose, raffinose, stachyose, sucrose, and total sugars in sesame seeds. Mean contents of these sugars were 0.95, 1.28, 2.22, 0.14, 0.82, and 5.39g/100g meal, respectively. These results also indicate that sugar contents in sesame whole seed could be manipulated by using specific growing conditions and cultivars. Our results indicated, for the first time, that sesame could be easily produced as a commercial crop in Virginia.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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