

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

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9 Contribution of Virginia State University Agricultural Research Station. The use of any trade names or
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11 suitable.

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13 **ABSTRACT**

14 Mean contents of fructose, glucose, raffinose, stachyose, sucrose, and total sugars in whole
15 sesame seed, produced during 2011 and 2012 in mid-Atlantic region of the United States of America,
16 were 0.95, 1.28, 2.22, 0.14, 0.82, and 5.39 g/100 g meal, respectively. Planting time effects were
17 significant for contents of fructose, stachyose, and sucrose. Early planting (Late May to early June)
18 resulted in 5.4 and 34.3% increase in contents of fructose and sucrose, respectively over late planting
19 (early July). On the other hand, early planting resulted in an increase of 70% in content of stachyose,
20 a non-nutritive sugar. An increase in row spacing from 37.5 cm to 75 cm increased the content of
21 fructose by 24.7% but resulted in 8.1% decrease in content of glucose. Cultivar effects were
22 significant only for sucrose. S26 and S32 cultivars had significantly higher content over that of 22K
23 (0.89, 0.89, and 0.69 g/100 g meal, respectively). These results indicate that sugar contents in
24 sesame whole seed could be manipulated by using specific growing conditions and cultivars and
25 could be helpful in determination of sugar intake via consumption of whole seeds.

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27 Keywords: *Sesamum indicum* L.; Total sugar content; Fructose content; Glucose content; Sucrose
28 content; Raffinose content; Stachyose content.

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31 1. INTRODUCTION

32 This study was conducted to determine if sesame (*Sesamum indicum* L., Pedaliaceae) could
33 be produced in a non-traditional area to diversify cropping system and to characterize composition of
34 sesame related to human nutrition. Sesame is one of the oldest crops known to humans.
35 International demand for sesame continues to increase every year. The world's traded sesame seed
36 recently surpassed one million tons per year and was valued at approximately \$850 million. In the last
37 15 years, world trade in sesame has increased by nearly 80%. The United States imports more
38 sesame than it grows. In 2010, the United States imported sesame seed valued at \$69.9 million which
39 was relatively unchanged from 2009 [1]. This observation indicates that there is potential for
40 enhancing sesame production in the United States. Due to significant reductions in tobacco (*Nicotiana*
41 *tabacum* L.) and peanut (*Arachis hypogea* L.) acreage in Virginia in recent times, the New Crops
42 Program of Virginia State University has been evaluating several summer crops that can be grown in
43 Virginia to help agricultural diversification and to enhance farm incomes. In this regard, sesame is
44 considered a potentially lucrative crop.

45 It is well established that foods determine human health. Given that all foods originate from
46 plants, it is imperative that composition of plant products to be used as foods be clearly known so that
47 informed decisions could be made regarding human nutrition. Diabetes and obesity are two of the
48 most critical health issues in the United States today, with millions of dollars poured into research
49 every year to further uncover the sources of this epidemic in order to cure/manage the disease.

50 Researchers at the Yale School of Medicine have uncovered a feed-forward mechanism whereby
51 excess sugar consumption may lead to increased fat production in the liver and the ensuing
52 development of diabetes [2]. Although there is a lack of dietary trials linking sugar consumption with
53 human diseases, it is commonly suggested that sugar consumption should be limited [3,4,5,6].

54 Through the ages, sesame seeds have been a source of food and oil. About 65% of the
55 annual sesame crop is processed into oil and 35% is used in food [1]. There is a complete lack of
56 information about sesame production in this region and additionally regarding composition of sesame
57 seed produced in this region. One objective of our research was to determine if sesame could be
58 successfully produced in Virginia. Additionally, we were interested in characterization of sugars in
59 sesame seed produced in the mid-Atlantic region of the United States of America to address issues
60 related to management of diabetes.

61

62 2. MATERIALS AND METHODS

63

64 2.1 Plant material and Production

65 Five proprietary sesame cultivars (22K, S26, S28, S30, and S32) from Sesaco Corporation (San
66 Antonio, Texas, USA) were used in this study. This field study was conducted at Randolph Farm of
67 Virginia State University located in Ettrick, Virginia. These cultivars were planted in four-row plots with
68 row spacings of 37.5 and 75 cm in an Abel Sandy Loam soil. Sesame was planted on May 23 and

69 June 8, respectively (PT1) during 2011 and on July 9 and July 17, respectively (PT2) during 2012
70 using a split-plot experimental design with planting dates as main plots, row spacings as sub-plots
71 and cultivars as sub-sub-plots with four replications of a Randomized Complete Block Design. The
72 soil received a pre-plant incorporated application of approximately 2 liters of trifluralin herbicide per
73 hectare. Seeding rate for this study was approximately 3 kg/ha, the plot length was 3 m and the seed
74 was planted on a flat bed. Seeding was accomplished using a four-row research planter. The
75 experimental area did not receive any irrigation. Upon maturity, the plots were harvested by using a
76 research combine.

77 The experimental area received a fertilizer application of 112 kg per hectare each of N, P, and
78 K. All plots were harvested manually at maturity, generally in November to December of each year.
79 Seeding rate for this study was approximately 3 kg/ha, the plot length was 3 m and the seed was
80 planted on a flat bed. The experimental area did not receive any irrigation. Upon maturity, the plots
81 were harvested by using a research combine.

82

83 2.2 Determination of contents of fructose, glucose, sucrose, total sugars, raffinose, and stachyose
84 contents in whole sesame seeds

85 Fructose, glucose, sucrose, raffinose, stachyose and total sugars in whole sesame seeds
86 were extracted from defatted ground sample and analyzed by high-performance liquid chromatograph
87 (HPLC) following the methods optimized by Johansen et al. [7]. Triplicate of 1.0 g of the defatted

sample was placed in 25 mL centrifuge tube and suspended in 2 mL 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 13000 rpm for 10 minutes, and 500 μ L of the clear supernatant was filtered through a syringe nylon membrane filter (25 mm diameter, 0.2 μ m; Waters Associates, Inc., Milford, MA USA). An aliquot of 20 μ L 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 5 μ m (250 x 4.6mm), preceded by a Prevail carbohydrate ES guard column 53mm x 7.0mm (Grace, Deerfield, IL USA). Column, sample and detector temperature were maintained, respectively, at 50, 25, 30 $^{\circ}$ C. The mobile phase, acetonitrile/water (75:25 v/v), was run isocratically at a flow rate of 1.0 mL/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/ 100 g oil-free meal.

107

108 2.3 Statistical analysis

109 All data were analyzed using the Analysis of Variance procedures in version 9.3 of SAS [8].

110 The means were compared using Fisher's Protected Least Significant Difference at a 5% level of
111 significance.

112

113 3. RESULTS AND DISCUSSION

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

117 Earlier planting (late May to early June) resulted in 0.98 g/100 g meal fructose content in
118 whole sesame seed whereas late planting (early July to middle of July) resulted in 0.93 g/100 g meal
119 fructose – an increase of 5.4% due to earlier planting. Similarly, early planting resulted in 34%
120 increase in contents of sucrose over late planting (0.94 and 0.70 g/100 g meal, respectively) in whole
121 sesame seed (Table 2). Early planting increased content of stachyose, a non-nutritive carbohydrate,
122 70% over late planting (0.17 and 0.10 g/100 g meal, respectively). Increasing the spacing between
123 rows from 37.5 cm to 75 cm resulted (Table 3) in an 24.7% increase in fructose content (1.06 and
124 0.85 g/100 g meal, respectively) and caused an 8.1% decrease in glucose content (1.33 and 1.23
125 g/100 g 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 0.69 g/100 g meal, respectively).

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.

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. 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 (37.5 cm between rows) or a wider row spacing (75 cm 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 37.5 cm or 75 cm 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 75 cm rows might be desirable.

4. CONCLUSIONS

Results of our study indicated that sesame could be easily produced as a commercial crop in Virginia. These results also indicate that sugar contents in sesame whole seed could be manipulated by using specific growing conditions and cultivars.

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194 Table 1. Partial analysis of variance (Mean squares) for contents of sugars

195 in seeds of five sesame cultivars grown using two planting dates and

196 two row spacings in Virginia during 2011 and 2012.

197

Variable	Years	Planting dates	Row spacing s	Cultivar s	R ² %	CV %	Mean
Fructose	*	*	**	ns	96.4	36.9	0.95 ^x
Glucose	ns	ns	**	ns	98.2	10.2	1.28 ^x
Sucrose	ns	*	ns	*	91.6	28.7	0.82 ^x
Total sugars	*	ns	ns	ns	95.4	12.7	5.39 ^x
Raffinose	*	ns	ns	ns	96.3	11.1	2.22 ^x
Stachyose	ns	**	ns	ns	94.4	46.3	0.14 ^x

198 *, **: Mean squares significantly different from residual mean squares at 5 and 1%

199 levels, respectively when tested against appropriate error mean squares as per split-plot

200 analysis.

201 x : Sugar contents as g/100 g meal.

202

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

205

Variable	Early planting (PT1)	Late planting (PT2)
Fructose ^x	0.98 a*	0.93 b
Glucose ^x	1.43 a	1.13 a
Sucrose ^x	0.94 a	0.70 b
Total sugars ^x	5.29 a	5.48 a
Raffinose ^x	2.08 a	2.37 a
Stachyose ^x	0.17 a	0.10 b

206 x : Sugar contents as g/100 g meal.

207 * : Mean within rows followed by similar letters were not different according to LSD at 5% level.

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

210

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

211 x : Sugar contents as g/100 g meal.

212 * : Mean within rows followed by similar letters were not different according to LSD at 5% level.

213 Table 4 . Cultivar differences for contents of sugars in seeds of sesame

214 produced using two row spacings and two planting dates in Virginia

215 during 2011 and 2012.

216

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

217 x : Sugar contents as g/100 g meal.

218 * : Mean within rows followed by similar letters were not different according to LSD at 5% level.