Technical Papers

Some Biometric Observations on Cacao Fruit

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During a program directed toward the selection of cacao trees of superior characteristics as parent stock for vegetative propagation of new planting material, a large amount of data derived from various physical measurements on cacao fruit was accumulated. These data were examined statistically to obtain a simple measurement that would serve as an index to the yield of dry cacao from an average fruit of a particular tree. The yield of dry cacao per tree is dependent upon the fruit produced and the weight of dry cacao per fruit. Direct determination of the former is relatively simple when compared with the latter. Therefore, a good indicator of the weight of dry cacao per fruit would be of value in selecting high-yielding stock.

The measurements analyzed in this study were made on samples containing 6–15 (an average of 10) fruit per sample. Trees were selected in the field on the basis of fruit counts and apparent disease resistance.

TABLE 1

STATISTICS OF FOUR ATTRIBUTES MEASURED ON 70 SAMPLES* OF FRUIT†

	Av wt individual fruit (g)	Av wt individual dry seeds (g)	Av no. seeds/fruit	Av wt dry cacao/fruit (g)
Mean	551	1.32	34	45
Median	517	1.27	34	43
Range	314–892	0.78–2.31	14–42	22–84
Coefficient of variation	28%	23%	15%	22%

* 6–15 (av 10) fruit per sample.
† Fruit harvested from trees in an old seedling population on the basis of fruit counts and apparent disease resistance.

These trees, 20 or more years of age, were located on farms representing the greater portion of plantings in the Bocas del Toro Province of Panama. They were derived from hybridization of Forestero and Criollo varieties of *Theobroma cacao*, with Forastero characteristics predominating. The fruit samples were carefully harvested at maturity (after the pulp surrounding the seeds became semiliquid and before the seeds sprouted) and were transported immediately to a laboratory, where the seeds were removed, processed, and dried so as to yield cacao containing 7 ± 1% shell and 6 ± 1% moisture.

The following measurements were made on 70 samples of fruit: (1) average weight of individual fruit, (2) average weight of individual dry seeds, (3) average number of seeds per fruit, and (4) average weight of dry cacao per fruit. The mean, median, range, and coefficient of variation of measurements of these four attributes were computed. As seen in Table 1, the average number of seeds per fruit was the least variable attribute, and the mean coincided with the median. The variations of the remaining three attributes were considerably greater and their means were higher than their medians. This undoubtedly means that trees bearing unusually heavy fruit, seed, or yield of dry cacao per fruit were selected more frequently than trees with unusually low values for these attributes.

TABLE 2

RELATIONSHIPS OF FOUR ATTRIBUTES MEASURED ON 70 SAMPLES OF CACAO FRUIT

		Av wt individual fruit	Av wt individual dry seeds	Av no. seeds/fruit
Av weight of dry cacao/fruit	Coefficient of correlation	0.59*	0.86*	0.50*
	Coefficient of regression	0.047†	34‡	1.30§

* $P = 0.01$.
† g dry cacao/g of fruit.
‡ g dry cacao/g dry seed.
§ g dry cacao/seed.

The relationships of average weight of dry cacao per fruit to the average weight of individual fruit, average weight of individual dry seeds, and number of seeds per fruit are shown by coefficients of correlation and regression in Table 2. The average weight of dry cacao per fruit is significantly correlated with the remaining three attributes. The most dependable index to this factor, however, is the average weight of individual dry seeds. In attempting to predict the average weight of dry cacao per fruit from the average weight of individual dry seeds, the standard error of estimate is 6 g. This is one half the standard deviation of the former attribute.

Pound (*1, 2*) investigated the variability of numerous physical measurements on cacao in Trinidad, but he made no attempt to correlate the attributes discussed in this study. To the writer's knowledge, no simple index to the yield of dry cacao per fruit has been developed. Nevertheless, those concerned with the selection of high-yielding cacao are aware of the importance of considering this factor of over-all yield.

Since dry seed weight is closely correlated with yield of cacao per fruit, we can conclude that the size of the fresh seeds as judged visually in the field is also a good index to this factor. If we use large seeds (along with fruit production of the tree) as a criterion for selection of high-yielding trees, we satisfy at the same time the desire of chocolate manufacturers for large, plump seeds.

References

1. POUND, F. J. *1st Ann. Rept. on Cacao Research.* Trinidad: I.C.T.A., 10 (1931).
2. ———. *2nd Ann. Rept. on Cacao Research.* Trinidad: I.C.T.A., 9 (1932).

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The Enzymatic Conversion of Lactose into Galactosyl Oligosaccharides

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The enzymatic synthesis of oligosaccharides from the disaccharides, sucrose and maltose, has been reported from several laboratories (*1–5*). Experiments with labeled substrates (*6, 7*) have shown that these oligosaccharides arise through transfructosidation and transglucosidation reactions. In this communication, we shall report preliminary studies on the enzymatic conversion of lactose into a series of galactosyl oligosaccharides. Evidence from tracer experiments indicates that a transgalactosidation mechanism is involved in the synthesis of the new oligosaccharides. From a consideration of the products of partial acid hydrolysis of the oligosaccharides and their aldonic acid derivatives, it appears that two of the new compounds are disaccharides (glucose-galactose and galactose-galactose) and two are isomeric trisaccharides (glucose-galactose-galactose).

Ten g CP lactose in 100 ml of water was treated with 100 ml of a 2% solution of a yeast enzyme preparation.[1] At the end of 24 hr the digest was heated in a boiling water bath for 5 min. The products in the digest were resolved by paper chromatography (*8*). Examination of the paper chromatogram (Fig. 1) revealed the presence of the new oligosaccharides. These oligosaccharides were not synthesized from glucose and galactose since an enzymatic digest of these substrates contained no new compounds. Further, a blank of the enzyme and the lactose showed that the oligosaccharides were not present in the original solutions. It is noted, however, that the enzyme blank contained two monosaccharides (fructose and glucose) as contaminants. Dialysis of the enzyme removed not only the monosaccharides but also some essential cofactor of the enzyme.

The new oligosaccharides (I, II, III, and IV) were isolated by paper chromatographic procedures previously described (*7*). Hydrolysis of the pure compounds in 0.1 *N* HCl showed that Compounds I, III, and IV are composed of glucose and galactose residues and that Compound II is composed of galactose residues. As judged from the intensity of the spots on the paper chromatogram, the glucose-galactose ratios appeared to be 1:1 for Compound I and 1:2 for Compounds III and IV.

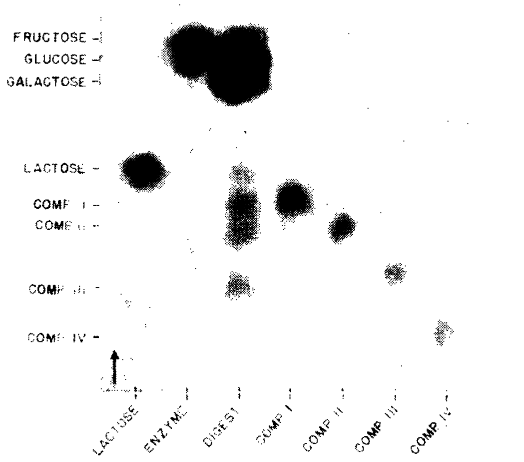

FIG. 1. A multiple ascent paper chromatogram of the lactose digest, of lactose and enzyme controls, and of the pure galactosyl oligosaccharides.

Two further lines of evidence point to the structure of the oligosaccharides. First, the apparent R_F values of the pure compounds (Fig. 1) are typical of oligosaccharides composed of two or three monosaccharide units joined through 1,4 or 1,6 glycosidic bonds (*7, 9*). Second, partial acid hydrolysis of the compounds and their aldonic acids yields the reducing products listed in Table 1. These hydrolytic products have been tentatively identified by a comparison of their R_F values with those of pure reference compounds. The structures suggested by these findings are: glucose-6,1-galactose for Compound I, galactose-6,1-galactose for Compound II, glucose-4,1-galactose-6,1-galactose for Compound III, and glucose-6,1-galactose-6,1-galactose for Compound IV.

There is a marked similarity in the mode of action

TABLE 1

REDUCING PRODUCTS OBTAINED ON PARTIAL ACID HYDROLYSIS OF THE GALACTOSYL OLIGOSACCHARIDES AND THEIR ALDONIC ACID DERIVATIVES

Oligosaccharides	Reducing products
Compound I	Glucose, galactose
Aldonic acid of Compound I	Galactose
Compound II	Galactose
Aldonic acid of Compound II	Galactose
Compound III	Glucose, galactose, lactose, Compound II
Aldonic acid of Compound III	Galactose, Compound II
Compound IV	Glucose, galactose, Compound I, Compound II
Aldonic acid of Compound IV	Galactose, Compound II

[1] The yeast concentrate "Lactase B" was kindly supplied by Rohm & Haas Co., Philadelphia, Pa. This concentrate possessed the transferring activity described in this report, as well as hydrolytic (lactase) activity.