INVESTIGATION OF THE RELATIONSHIP AMONG QUALITY OF CHOPPED SUGARCANE VOLUMETRIC WEIGHT AND LOADING COEFFICIENT OF TRANSPORTATION

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ABSTRACT

This paper deals with the results of investigation of the volumetric weight of chopped sugarcane, the analysis of relationship between volumetric weight and contents of extraneous matter, the biological yield of sugarcane, length of billets and the loading coefficient of trailers.

Based on this analysis we came to the following conclusions: that weight of chopped vegetable mass volumetricness ranged from 300 to 330 kg/m³, the trailer loading coefficient varied from 0.28 to 0.31 when yields of cane fields were from 106.6 to 157 mt/ha and the contents of extraneous matter ranged from 12% – 28%.

INTRODUCTION

Mechanization of sugarcane harvesting is one of the main tasks of Cuba’s complex mechanization problem of sugarcane production. Generally, during harvesting a great number of men day/ha is employed and this number is increased in the rainy season. The complete mechanization of such a laborious work is necessary because sugarcane must be harvested during a very short lapse of time in order to avoid losses in sucrose content, and at the same time prepare cane fields for cultivation of ratoons (Betancourt1, 2, 3 and Gonzalez4, 5).

In order to reduce labor in the sugarcane production it is necessary to significantly increase the level and rate of mechanization of all of these works, mainly during harvesting season (Hurtade6).

The performance of this task depends to a great extent on crop quality, the stalks chopped by combine harvester, cleanliness of elaborated vegetable mass, its volumetric weight and the loading coefficient of transportation media. The coordinated work of combine-harvester with transportation media has also an influence, Peralta, Dominguez and Fonseca6, 9.
The objective of the study is mainly to explain the influence of the extraneous matter content on the volumetric weight of vegetable mass chopped and on the loading coefficient of trailer.

MATERIALS AND METHODS

During the harvesting process performed by KPT-1 combine harvester, chopped stalks first went to the longitudinal conveyor and then to the discharge conveyor.

During their transport, chopped stalks were separated by means of a fan into heavy fractions (bills) and light fractions (trash and green leaves). Light fractions were expelled outside and heavy fractions were dropped into the trailer that went along the combine harvester.

On the other hand, a portion of the light fractions (extraneous matter) were also dropped into the trailer and had a negative influence on the volumetric weight of the vegetable mass and on the loading coefficient, while the length of chopped billets had a negative influence on the above factors.

Obtaining real numerical values of the contents of extraneous matter, volumetric weight of elaborated vegetable mass and the loading coefficient was therefore essential in order to determine optimum shapes and sizes of trailers.

In order to make a study on these, special field and laboratory trials were conducted.

Harvesting and chopping of sugarcane stalks were carried out by means of a KPT-1 sugarcane combine harvester for sugarcane variety Ja. 60-5. The time consumed for the loading operation up to the upper edge of a trailer was measured with a chronometer. Afterwards, all the vegetable mass contained in each trailer was weighed by means of a scale. To determine the productivity of the harvester, the harvested areas were measured simultaneously.

Experiments were conducted in the field with different biological yields. Usually, the volume of harvested vegetable mass is calculated by the formula:

\[ \delta^4 = \frac{Q}{sv} \]

where:
\- Q: weight of harvested vegetable mass, kg
\- v: volume of trailer, m³
\- s: specific weight of clean cane, g/cm³

Vegetable mass chopped during harvesting was made up of the following com-
ponents:

a. clean cane
b. trash and dry stalks
c. tops
e. suckers

These components had different moisture contents. To determine the total weight of harvested vegetable mass it was necessary to take into account the differences in moisture content of the different constituents.

The experiment had 10–20 replicates. Samples of each component were weighted separately and moisture samples were taken from each.

From clean cane, samples of 100 units were taken to measure length and diameter of stalks. The length of stalk pieces was measured from one end to the other by using a measuring tape, and the diameter was measured by means of a vernier caliper.

Obtained values by means of calculation were allowed to take the weight of components to a supposedly uniform moisture system. Afterwards, the % content of each component was finally calculated. These data were able to correlate some relationship between volumetric weight and extraneous matter content.

RESULTS

A. Changes in components of extraneous matter content depending on the biological yield of sugarcane. Results of this investigation are shown in Fig. 1.

The clean cane % content of harvested vegetable mass increased proportionally with biological yield of sugarcane, although to a certain extent (138.3 mt/ha) the increase is not significant. Thus, when biological yield of sugarcane ranged from 106.5 mt/ha to 138.3 mt/ha, the clean cane % content increased by 11.15% and when biological yield increased from 138.3 mt/ha up to 157.7 mt/ha there was a 4.47% increase.

Tops % content in harvested vegetable mass decreased with an increase in biological yield. Thus, with an increase in biological yield from 106.5 mt/ha to 138.3 mt/ha (Fig. 1 curve b), tops content decreased by 11.80%, and afterwards, with an increase in the biological yield up to 157.7 mt/ha, tops % content was almost constant.

Trash and dry stalk % content in harvested vegetable mass decreased with an increase in the biological yield of sugarcane. It should be pointed out that dec-
FIGURE 1. Variations in the weight of clean cane (% cc) and components of extraneous matter (EM) depending on the biological yield of sugarcane ($Q_B$).

...increase in trash and dry stalks (Fig. 1, curve c) was significantly remarkable with sugarcane biological yields up to 138.3 mt/ha, having no influence in the trash and dry leaves content of harvested vegetable mass and later increase in yield. Thus, with an increase in biological yield from 106.5 to 138.3 mt/ha the dry leaves and dry stalks % content of harvested vegetable mass decreases 2.3 times, but with an increased biological yield of sugarcane from 138.3 to 157.7 mt/ha it decreased 1.2 times. This was due to the fact that the dry cleaning system of sugarcane harvested was not able to entirely separate extraneous matter from the harvested vegetable mass. In Fig. 1 (curve a) it is clearly seen that chopped clean cane % content of harvest vegetable mass did not increase significantly with an increase in the biological yield.

Suckers % content in the harvested vegetable mass did not change significantly with an increase in biological yield of sugarcane. Thus, with an increase of biological yield of sugarcane from 106.5 to 157.7 mt/ha Fig. 1 (curve d) suckers % content in the harvested vegetable mass only decreased 1.23 times. This phe-
FIGURE 2. Variations in the volumetric weight of harvested vegetable mass \( f \) extraneous matter \( EM \) and loading coefficient of tractor \( k \) depending on the biological yield of sugarcane \( Q_B \).

nomenon could be explained by the fact that when sugarcane yields were high there were no proper conditions for the suckers to grow.

B. Changes in extraneous matter content, volumetric weight of harvested mass and loading coefficient of trailers depending on biological yield of sugarcane. Results of this investigation are shown in Fig. 2.

From Fig. 2 (curve a), with an increase in the biological yield of sugarcane, there was a decrease in the extraneous matter content \( EM \). At the beginning there was a significant decrease and later on it became not significant, because the increase in the sugarcane yield was due to an increase in the length and thickness of these stalks. In this case the number of tops remained the same.

The insignificant reduction of extraneous matter content in the trailer was due to a decrease in the amount of trash in the harvested vegetable mass which depended on the cleaning capacity of the harvester. Thus, with an increase in the biological yield of sugarcane from 106.5 to 138.3 mt/ha, the extraneous matter
content decreases 1.8 times, but with an increase in yield from 138.3 mt/ha. 157.7 mt/ha there was a 1.26 decrease.

In Fig. 2 (curve b) it is also seen that with an increased biological yield of sugarcane, i.e. with an increase in the weight of harvested vegetable mass in the trailer, the volumetric weight of harvested vegetable mass increased significantly at the beginning and not significantly, afterwards. Thus, with an increase in biological yield from 106.6 to 121.6 mt/ha, the volumetric weight of elaborated vegetable mass increased by 8%, but with an increase in yield from 138.3 to 157.7 mt/ha, the volumetric weight of the elaborated vegetable mass increased by only 2.4%.

Changes in the loading coefficient of the trailer indicated the part of the total volume of the trailer was loaded with chopped clean cane. In order to determine the loading coefficient of the trailer, the following formula is used:

\[
K = \frac{q_m}{S V_t}
\]

Where:
- \(K\) : loading coefficient of trailer
- \(q_m\) : weight of harvested vegetable mass, kg
- \(S\) : specific weight of clean cane, kg/m³
- \(V_t\) : volume of trailer, m³

Specific weight of clean cane was experimentally determined as

\[S = 1055 \text{ kg/m}^3\]

Obtained data depending on biological yield of sugarcane is shown in Table 1.

**TABLE 1.** Values of main parameters depending on biological yields of sugarcane

<table>
<thead>
<tr>
<th>No. of sugarcane order</th>
<th>Biological yield of sugarcane MT/ha</th>
<th>Weight of harvested vegetable mass in trailer kg</th>
<th>Weight of chopped clean cane kg</th>
<th>Extraneous matter in harvested vegetable mass %</th>
<th>Volumetric weight of harvested vegetable mass kg/m³</th>
<th>Loading coefficient of trailer with chopped clean cane Kg/trailer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>157.7</td>
<td>4928.41</td>
<td>4328.15</td>
<td>12.18</td>
<td>328.55</td>
<td>0.311</td>
</tr>
<tr>
<td>2</td>
<td>138.3</td>
<td>4896.03</td>
<td>4191.98</td>
<td>14.24</td>
<td>326.34</td>
<td>0.309</td>
</tr>
<tr>
<td>3</td>
<td>138.3</td>
<td>4844.13</td>
<td>4045.82</td>
<td>16.48</td>
<td>322.94</td>
<td>0.308</td>
</tr>
<tr>
<td>4</td>
<td>121.6</td>
<td>4837.79</td>
<td>3975.70</td>
<td>17.82</td>
<td>322.52</td>
<td>0.306</td>
</tr>
<tr>
<td>5</td>
<td>121.6</td>
<td>4819.25</td>
<td>3874.68</td>
<td>19.60</td>
<td>321.28</td>
<td>0.305</td>
</tr>
<tr>
<td>6</td>
<td>121.6</td>
<td>4771.54</td>
<td>3693.18</td>
<td>22.60</td>
<td>318.10</td>
<td>0.302</td>
</tr>
<tr>
<td>7</td>
<td>111.1</td>
<td>4745.81</td>
<td>3590.21</td>
<td>24.35</td>
<td>316.39</td>
<td>0.300</td>
</tr>
<tr>
<td>8</td>
<td>111.1</td>
<td>4694.79</td>
<td>3476.96</td>
<td>25.94</td>
<td>312.99</td>
<td>0.294</td>
</tr>
<tr>
<td>9</td>
<td>106.5</td>
<td>4469.72</td>
<td>3203.90</td>
<td>28.32</td>
<td>297.98</td>
<td>0.282</td>
</tr>
</tbody>
</table>
Based on the data from Table 1, Fig. 3 was plotted. From curve c it is seen that with an increase in the weight of harvested vegetable mass and also with an increase in biological weight of sugarcane, the loading coefficient of the trailer with chopped clean cane (billets) increased. For example, if weight of harvested vegetable mass in trailer was 4,928 mt, the loading coefficient was 0.31, that is, 31% of the trailer’s volume was filled with harvested chopped clean cane (billets) the remaining of the trailer’s volume i.e. 69% was not used since it was filled with extraneous matter and empty spaces. When the weight of harvested vegetable mass in the trailer was 4,469 mt the loading coefficient was 0.28 that is, 28% of trailer’s volume was filled with clean cane and the remainder of the trailer’s volume was filled with extraneous matter and empty spaces.

C. Changes in the volumetric weight of harvested vegetable mass weight of clean cane and increase in transportation media depend on the content of extraneous matter in harvested vegetable mass.

![Figure 3. Variations in the volumetric weight of harvested vegetable mass (q_m), extraneous matter (EM) and loading coefficient of trailer (K) depending on the biological yield of sugarcane (Q_B).](image-url)
The influence of extraneous matter content of harvested vegetable mass in its volumetric weight and weight of clean cane is shown in Fig 4.

From the analysis of the obtained data (Fig. 4 curves a and b) volumetric weight of harvested vegetable mass and weight of clean cane decreased with an increase in extraneous matter content. Thus, when extraneous matter content in the harvested vegetable mass reached 12.18%, its volumetric weight equally 328.55 kg/m³ and when contents of extraneous matter was greater than 20%, volumetric weight abruptly decreased.

An increase from 2.5% to 3.0% in the extraneous matter content involved a 1% decrease in volumetric weight and a 4% decrease in clean cane weight. By knowing the relationship between extraneous matter content and the volumetric weight of elaborated vegetable mass as well as the weight of clean cane it was possible to determine the increase of transportation media as far as weight and volume was concerned.

According to the data from the Agronomics Laboratory of the Machinery Construction Research Center (CICMA) during 1977, the increase in weight and volume of transportation media was determined by the following formula:

\[ \Delta t_v = \frac{3.06 \times EM}{100 - EM} \]

where: \( EM = \) extraneous matter % content of harvested vegetable mass in the trailer
\( q_{cc} = \) weight of clean cane in the trailer, kg
3.06 = constant multiplier depending on specific weight of sugarcane

By using formulas (2 and 3) the final value reached by the rate of transportation in weight and volume was found. Obtained data is shown in Table 2.

Based on data from Table 2, Fig. 4 was plotted which is the rate of change of transportation media in volume and weight depending on extraneous matter content in the harvested vegetable mass.

From Fig. 4 (curves c and d) it is seen that with an increase of extraneous matter content, there was an increase in weight and volume of transportation media.

Thus, when extraneous matter content in harvested vegetable mass reached
TABLE 2. Values of transportation increment depending on the extraneous matter content

<table>
<thead>
<tr>
<th>No. of order</th>
<th>Weight of clean cane q_{cc} kg</th>
<th>Volumetric weight of harvested vegetable mass kg/m³</th>
<th>Extraneous matter content in vegetable mass kg</th>
<th>Increment in transportation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>4328.15</td>
<td>328.55</td>
<td>600.28</td>
<td>13.86</td>
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<tr>
<td>2</td>
<td>4197.98</td>
<td>326.34</td>
<td>697.05</td>
<td>16.60</td>
</tr>
<tr>
<td>3</td>
<td>4045.82</td>
<td>322.94</td>
<td>798.31</td>
<td>19.73</td>
</tr>
<tr>
<td>4</td>
<td>3975.70</td>
<td>322.52</td>
<td>862.09</td>
<td>21.68</td>
</tr>
<tr>
<td>5</td>
<td>3874.68</td>
<td>321.28</td>
<td>944.57</td>
<td>24.38</td>
</tr>
<tr>
<td>6</td>
<td>3893.18</td>
<td>318.10</td>
<td>1073.36</td>
<td>29.20</td>
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<tr>
<td>7</td>
<td>3590.21</td>
<td>316.39</td>
<td>1155.60</td>
<td>32.19</td>
</tr>
<tr>
<td>8</td>
<td>3476.86</td>
<td>312.99</td>
<td>1217.83</td>
<td>35.02</td>
</tr>
<tr>
<td>9</td>
<td>3203.90</td>
<td>297.96</td>
<td>1265.82</td>
<td>39.51</td>
</tr>
</tbody>
</table>

FIGURE 4. Variations of volumetric weight of harvested vegetable in trailers depending on length (L) and diameter (d) of billets.

14.24% the increase in weight and volume of transportation media was 16.6 and 50.64%, respectively, but when extraneous matter content reached 26%, the increase in volume and weight of transportation media increased 50.64% and 16.6%, respectively. This means that a 1% increase in the extraneous matter content involved an increase in the rate of transportation in weight and volume from 1 to 1.25% and from 3.5 to 4%, respectively.

D. Influence of billet's length and their diameter in the volumetric weight of
harvested vegetable mass. Fig. 5 shows the influence of chopped stalks and their diameter on the volumetric weight of harvested vegetable mass.

The analysis of data (Fig. 5), showed that with an increase in the length of chopped billets, the volumetric weight of harvested vegetable mass decreased, on the other hand volumetric weight increased with the diameter.

It should be pointed out that an increase in the billet’s length over 330 mm (when billet’s diameter is from 23 to 27 mm) involved a rough decrease in the volumetric weight of harvested vegetable mass.

Thus, with equal stalk diameters and billets length from 250 to 320 mm, the volumetric weight of harvested vegetable mass decreased by 8% compared to billets with lengths equal to 250 mm.

Stalks with thickness up to 25 mm involved an increase in volumetric weight of harvested vegetable mass.

A continuous increase in stalks’ thickness did not involve a significant increase in volumetric weight. Thus, when the thickness of stalks was 25 mm, volumetric weight of harvested vegetable mass was approximately equal to 323.56 kg/m³, but when the thickness of stalks was equal to 26 mm, volumetric weight of harvested vegetable mass increased by 1.3% compared to stalks with a thickness of 23 mm. It is necessary to point out that volumetric weight of harvested vegetable mass depended not only on variation of parameters such as length of billet and stalk thickness, but also in the way in which vegetable mass was placed in the trailer and its density. Besides volumetric weight depends on the geometry of the trailer.

E. Determination of the necessary number of trailers to keep the uninterrupted work of combine harvesters.

In order to keep a steady flow of harvested vegetable mass to the sugarcane conditioning center or sugar mill, the whole productivity of cane trailers or trucks should be in agreement with feasible productivity of sugarcane combine harvester. In this case, the number of trailers (trucks) N should be optimum for the specific kind of work.

The minimum work output in the harvesting and transportation of the vegetable mass to be harvested should be taken optimization criterion. In other words, the problem is to find such a quantitative and qualitative relationship between combine harvesters and transportation media that allow to reduce interruptions to a minimum.

During harvesting of sugarcane with KPT-1 combine harvester, harvested vegetable mass was simultaneously loaded in the trailer (trucks) that travelled along
the side of the combine harvester. In this case, the necessary number $N$ of trailers (trucks) for a continuous transportation of harvested vegetable mass was determined from the following formulas:

$$N - 1 = \frac{W_{cp}}{Q_{tc}} \left( \frac{2L}{V_{tr}} + T_{ut} + T_{ft} \right)$$

where:

$$T_{tt} = T_{tt} = \frac{Q_{tc}}{W_{cp}}$$

and

$$T_{tt} = \frac{2L}{V_{tr}} + T_{ut} + T_{ft}$$

$T_{tt}$ = total lapse of time to load a trailer, min.

$Q_{tc}$ = load capacity of a trailer, kg

$W_{cp}$ = capacity of combine harvester kg/min.

$T_{tt}$ = transportation time, min

$T_{ut}$ = time necessary to unload a trailer including other time, min

$T_{ft}$ = loading time of a trailer, min

$L$ = distance m from the cane field to the sugarcane conditioning center (sugar mill).

By means of the above formula the number of trailers for different combine capacities and distances from cane field to the sugarcane conditioning center (sugar mill) could be calculated. Transportation average speed was experimentally found to be 15 km/hour. Average loading time was 16.5 min and average unloading time 7.1 min. In practice it was very difficult by means of calculation to determine the number of trailers because it depended on cane yield, kind of combine harvester and its productivity as well as on the distance from the cane field to the sugarcane conditioning center (sugar mill).

For the above reason and in order to make a quicker determination of the number of trailers under production conditions a special nomogram has been devised (Fig. 6). The nomogram was made in the following manner. Fig. 6 in quadrant I shows change in combine capacity (ha/hour) depending on sugarcane yield 9 mt/ha. Quadrant II shows relationship between combine capacity (ha/hour) and harvested vegetable mass mt/ha. Quadrant III shows the relationship between amount of harvested vegetable mass and the distance from cane field to the sugarcane conditioning center. To use the nomogram, the following steps should be taken:

Based on the harvesting machinery available, yields, and distances for transportation of sugarcane, and also by means of Fig. 6, the number of transportation
media (trailers and trucks) necessary to carry the harvested vegetable mass could be
determined. For example, for harvesting of sugarcane a KPT-1 sugarcane combine
harvester should be used. The distance from the cane field to the sugarcane condi-
tioning center (sugar mill) is 5 km. and sugarcane yield is 1000 MQ/ha. It is
necessary to determine the number (N) of trailers for an uninterrupted transpor-
tation of harvested vegetable mass to the sugarcane conditioning center (sugar mill).

1. On scale of right upper quadrant mark out the chosen yield (1000 MQ/ha),
and trace a vertical lineup to the intersection with the graph that characterizes
the variation of combine capacity and from it we extend a horizontal line up to the
intersection with the 1000 MQ/ha curve. From this point draw a vertical line down
to the intersection with the 5 km. curve and from it trace a horizontal line up to
the intersection with the vertical line corresponding to the number of trailers. In
this way the necessary number of transportation media to be employed could be
determined.

2. By adding one more unit to the above number (i.e. the trailer that’s being
loaded) we obtain the number N of trailers necessary to supply to the combine
harvester; in this case, 5 trailers.

FIGURE 6. Nomogram for determining the number of trailers under production
condition.
CONCLUSIONS

From the results of the data obtained from the investigation of the interrelationship among quality of chopped stalks, volumetric weight and loading coefficient of transportation media the following conclusions are established:

1. The degree of cleanliness of the harvested vegetable mass is influenced by the following factors.
   
a) Morphological characteristics of variety, cultivation conditions (age, development degree, lodging of stalks), and grass covering
   
b) Technical conditions of combine harvester, setting and qualification of operator
   
c) Moisture degree of cultivation

2. With an increase in the biological yield from 106.5 MT/ha to 157.7 mt/ha tops content decreased from 8.52% to 5.83%, trash decreased from 11.95% to 3.36% and suckers from 1.52% to 1.18%. A later increase in the biological yield produced unimportant variations in the components of extraneous matter.

3. With the increase in the biological yield form 106.5 mt/ha to 157.7 mt/ha volumetric weight of harvested vegetable mass increased from 297.98 kg/m³ to 328.55 kg/m³ while extraneous matter content in the harvested vegetable mass decrease from 28.32% to 12.32% to 12.18%.

4. With an increase in the extraneous matter content from 12.18% to 28.32% the transportation media in weight and volume also increased from 13.86% to 39.51% and from 42.90% to 120.50%, respectively, i.e a 1% increase in extraneous matter content increased the average of transportation rate ΔT_q from 1% to 1.25% and ΔT_v from 3.5% to 4.0%.

5. Results showed that with an increased billet’s length from 25.17 to 33.94 cm, volumetric weight of harvested vegetable mass decreased from 333.71 kg/m³ to 264.19 kg/m³.

6. When the diameter of harvested stalk pieces decreased from 26.27 to 23.10 mm volumetric weight also decreased from 333.71 kg/m³ to 264.19 kg/m³.

7. The analytic functions that were obtained and the nomogram made from these determined the necessary number of trailers for an uninterrupted work during harvesting of sugarcane.
REFERENCES


INVESTIGACION DE LA RELACION ENTRE LA CALIDAD DE LA CAÑA DE AZUCAR TROJADA, SU PESO VOLUMETRICO, Y EL COEFICIENTE DE CARGA EN LOS REMOLQUES

Urioste A. Peralta Abreu, Alchibay Abdurakirov, Manuel Fonseca y Miguel Dominguez

RESUMEN

Este artículo trata sobre los resultados de investigación del peso volumétrico de caña de azúcar trozada, un análisis de relación entre
peso volumétrico y contenido de materia extraña, el rendimiento biológico de la caña, el argo de los trozos y el coeficiente de carga de los remolques.

Basandonos en este análisis, llegamos a las siguientes conclusiones: el peso volumétrico de materia vegetal alimentada a la trozadora fluctúa de 300 a 330 kg/m³, el coeficiente de carga de remolque varía de 0,28 a 0,31 cuando el rendimiento de los campos es de 106,6 a 157 T/ha y el contenido de materia extraña fluctúa entre 12 — 28%.