Viscosity of Cuban molasses

RAUL BOUE MONTERO*
Polytechnical Institute Jose Antonio Echeveria Habana, Cuba

The exact knowledge of the rheological properties of different raw materials and products is of great importance in the sugar industry. The viscosity is one of the fundamental parameters in process of crystallization of the saccharose. The rate of flow through pressure filters, through beds of granular bone charcoal, or through the sugar wall in a centrifugal machine is *limited by the viscosity of the sugar liquor*. The facts mentioned above make understandable that the rheological properties of different juices occuring in sugar technology and also molasses were investigated by many research workes.

A short review about the viscosity of molasses is given by *Sólyom* and *Lásztity* (1) and also by *Honig* (2). Concerning the rheological character of molasses the opinions of different research workers are in many cases contradictory. *Honig* (3), *James and Lawrence* (4), *Gromkovskii* (5), *Graham* (6), *Schneider* and *Emmerich* (7), *Wilkes* and *Jennings* (8), *Drago* and *Delavier* (9) on the basis of the results obtained on the investigated molasses suppose that the molasse have newtonian fluid character. Only the authors mentioned latest (9) have made an objection that the growing quantity of colloidal substances may change the rheological character of the molasses.

Other authors, among them *Brooks* (10), *Emmerich* and *Fincke* (11), *Delavier* and *Smolnik* (12), *Moritzagu and Sloane* (13), *Devillers* and *Phelligut* (14), *Bhattacharyya* (15), *Kolarov* and *Garcell* (16) and *Hinog* (3) report about the non newtonian character of molasses. For the quantitative characterization of the viscosity of molasses they propose the use of Frankel equation

$$\mu = A \cdot 10^{B/T}$$

where μ = viscosity
A, B = constants
T = temperature

Waterman propose the use of the following equation

$$\ln(\mu/\varrho) = \frac{1}{T^x} + \text{constant}$$

where ϱ is the density of sugar solution.

* Jelenleg aspiráns a BME Biokémiai és Élelmiszertechnológiai Tanszékén

For the sugar solutions containing in greater quantity of other components a new equation was proposed by Pidoux

$$\log \mu = A + B\,(T-273{,}15)\,T^2$$

Similar equation was proposed by Misra

$$\ln(\mu) = a - bT + cT^2$$

Kolarov and Garcell (16) obtained good results using the following formula:

$$\lg(\mu) = \log(A) - B\log(T)$$

These authors inwestigated many molasses of sugar factories in Cuba. All equations show the big importance of the temperature in determining the viscosity of molasses.

Concerning the effect of dry matter content of molasses on the rheological properties Kaganov proposed the use of the following equation

$$\log(\mu) = \frac{\mathrm{Bx}}{1-\mathrm{r}} + \mathrm{const.}$$

where Bx = sugar content expressed in Brix grades
r = dry matter content

This equation was used in sugar industry for the calculation of the viscosity of different sugar solutions with good results. The calculated viscosity was in good agreement with the real values.

Henry modified the equation of Kaganov

$$\log(\mu/\varrho) = \frac{\mathrm{A}}{1-\mathrm{r}} + \mathrm{Bx}$$

where ϱ = density of sugar solution.

For the calculation of viscosity of sugar cane molasses the following equation was proposed by Atherton

$$\log(\mu) = A.\,Bx + \mathrm{Const.}$$

Kolarov and Garcell (16) used the equation:

$$\log(\mu) = a + b\log(\mathrm{L})$$

where a, b = constants

$$\Gamma = \frac{\mathrm{Bx}}{1-\mathrm{Bx}}$$

The results were statisfactory in the temperature range 40–50 °C.

The effect of dry substance on molasses viscosity can be described by the dry substance water ratio as proposed by *Kolarov* and *Garcell* (16) as follows:

$$\mu = A\,[DS/(100-DS)]^B$$

An equation expressing molasses viscosity in termin of dry substance, temperature, purity and reducing sugar ash ratio was proposed by *Ronillard and Koenig*

$$\mu a = \frac{2{,}03 \times 10^{-17}\,(DS/(100-DS))^{5{,}82}}{\left[\frac{T-273{,}5}{T^2}\right]^{4{,}45} e^{(0{,}1S7/S/NS^3+0{,}689/RS/A)}}$$

According of the investigations of *Drago* (9) NH_4Cl and KCl decreased the viscosity of molasses and on the other side K_2CO_3, NaCl, Na_2CO_3 and sodium glutamate had on opposite effect.

Carragana et al. and *Rubio et al.* also observed the increasing effect of NaCl and $CaCl_2$ on the viscosity of molasses. The KCl had no effect on the viscosity.

Aranjo, Giacomo and Pereira investigated different molasses in Brazilia. It was stated that the molasse containing the highest quantity of colloid substances had the highest viscosity. *Kolarov and Garcell* (16) express the wiew that the colloidel substances have the major effect on the viscosity of molasses.

In the framework of our research work the viscosity of molasses from cane sugar factories in Cuba were investigated. On the basis the results the rheological character of molasses was studied.

Materials and methods

27 molasse samples obtained during a sugar producing period from a sugar factory in Cuba were investigated.

For the characterization of the samples the following analytical measurements were realized:

- determination of concentration expressed in Brix grades by on areometer (17) in diluted (1:1) samples
- content of reductones and total sugar determined by volumetric method of *Lane and Eynon* (18)
- determination of ash content by sulphate method (18)
- determination of colloid substances by the method of *Ruff and Withrow* (19)
- nitrogen content by micro Kjeldahl method (20)
- colorimetric determination of P_2O_5 content

All the methods used are in accordance with the prescriptions of the ICUMSA and ISSCT.

The determination of rheological properties of molasses was realised by a rotation viscosimeter (Type: Rheotest, GDR) at the following temperatures: 40 °C, 50 °C, 60 °C, 70 °C and 80 °C.

For the investigation of the effect of dry matter content diluted samples with a dry matter content of 70, 75 and 80 Bx° were also investigated.

Results and discussion

The characteristic data of the molasse samples investigated are summarized in the Table 1. The values are similar to that obtained by *Kolarov* and *Garcell* (16) and alsp *Aranjo, Giacomo and Pereira*.

Table 1.

Characteristics of molasses

Molasses	Brix	Polarisation	Reducting sugar %	Total sugar %	Ash %	Gum* %	Nitrogen %	Phosphorus % (10^3)
1	86.42	35.38	20.5	67.8	7.22	0.57	–	–
2	88.94	36.2	18.35	62.79	9.20	1.30	0.17	1.0
3	88.48	36.3	21.6	57.91	7.14	4.27	0.35	1.0
4	88.16	28.8	20.7	64.91	6.64	3.08	0.28	2.0
5	89.0	27.96	22.0	66.10	9.34	5.16	0.14	–
6	89.5	32.40	23.7	71.7	9.34	2.02	0.21	7.0
7	87.56	26.6	20.5	65.23	10.93	4.47	0.22	2.0
8	86.96	28.44	20.4	62.0	8.34	–	–	1.3
9	89.62	37.60	19.1	65.31	11.57	3.20	0.22	4.0
10	84.80	36.0	19.0	65.90	5.74	3.66	0.14	8.0
11	87.20	25.0	19.4	67.50	8.63	3.41	0.35	1.5
12	88.00	47.4	19.1	68.20	10.29	4.93	0.21	3.25
13	88.04	30.48	20.2	64.6	7.59	–	0.07	1.8
14	87.24	42.00	17.0	73.7	5.9	4.46	0.14	9.8
15	83.80	35.7	19.4	68.3	9.7	4.32	0.42	1.0
16	88.46	51.2	20.1	69.6	7.84	0.28	0.28	2.0
17	85.80	26.4	18.4	61.5	10.32	4.32	0.22	2.0
18	87.80	26.4	19.2	61.5	6.97	4.46	0.28	–
19	86.32	36.1	18.3	63.5	12.73	4.01	0.42	2.0
20	86.28	37.0	10.8	65.11	–	–	0.28	8.0
21	86.26	32.8	18.5	63.34	11.08	2.89	0.22	3.5
22	85.12	33.0	18.2	64.7	6.14	6.20	0.21	4.8
23	86.42	32.4	18.1	65.7	–	7.93	0.35	–
24	85.08	26.48	18.4	67.2	9.90	4.69	0.21	7.0
25	88.02	28.0	18.0	66.0	–	4.38	0.35	1.5
26	85.44	28.2	19.6	68.6	6.92	0.34	0.21	7.0
27	85.64	27.0	21.7	71.4	7.10	5.34	0.14	6.7

* Dextrans

The rheological properties of the molasses investigated may be characterised by an equation of Ostwals and Walke

$$\tau = K\,(D)^n$$

where τ = stress
K = index of consistency
D = strain
n = index of pseudoplasticity.

In the Table 2 the values of consistency indexes (K) and pseudoplasticity indexes (n) are summarized. The fiducial limits were calculated by the Student's method at 95% level.

The Figure 1. shows the change of the consistency index of samples with the temperature. This correlation may be expressed by the following equation.

$$\ln(\mathrm{K}) = \ln(\mathrm{A}) + \mathrm{B}\ln(\mathrm{T}) \text{ or}$$
$$\mathrm{K} = \mathrm{AT}^{B}$$

It is also possible to use the equation

$$\ln(\mu) = a + b\ln(\Gamma)$$

$$\text{Where } \Gamma = \frac{\text{Brix}}{\text{100-Brix}}$$

The values of a and b are depending from the strain and temperature.

It was not possible to find a correlation between the viscosity and content of colloidal substances.

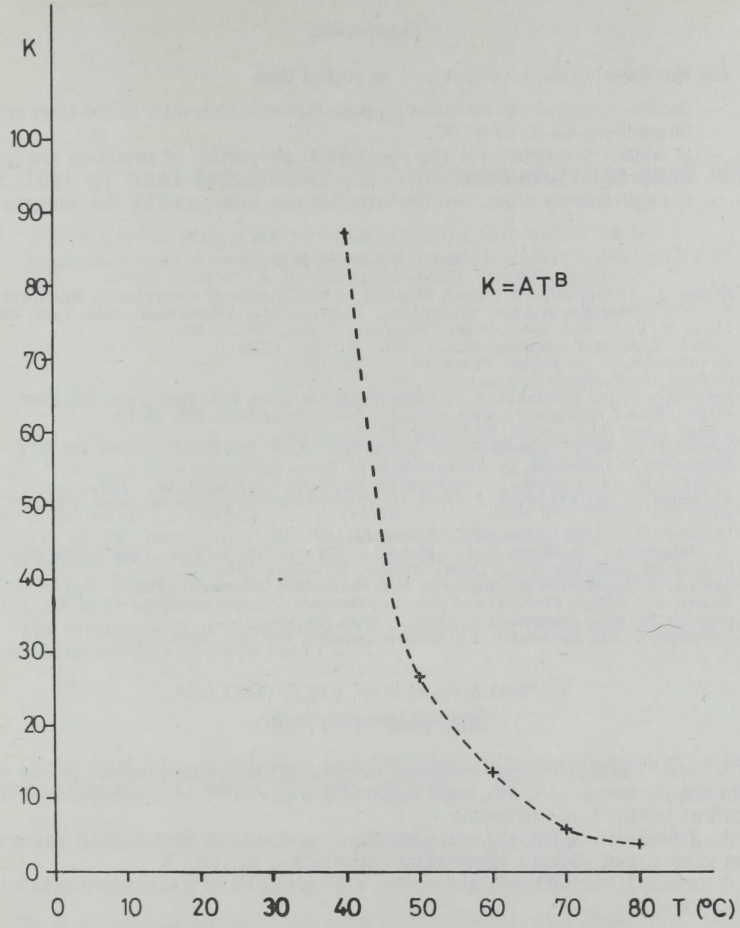

Fig. 1.
Change of consistency index with temperature

Table 2.

Parameters $\overline{n}$ and $\overline{K}$ for molasses

T (°C)	$\overline{n}$	$k = \left(\frac{gr \cdot s^{n-2}}{cm}\right)$
40	0,915 ± 0,020	27,20 ± 8,31
50	0,941 ± 0,018	26,51 ± 4,27
60	0,958 ± 0,012	13,29 ± 1,55
70	0,973 ± 0,017	5,81 ± 0,64
80	0,973 ± 0,017	3,96 ± 0,64

Conclusions

On the basis of the results it can be stated that

- the investigated molasses have a pseudoplastic character in the temperature range from 40 °C to 80 °C.
- at higher temperatures the rheological properties of molasses are nearer to the Newtonian fluid
- the concistency index and the viscosity are influenced by the temperature.

LITERATURE

(1) *Sólyom L.– Lásztity R.:* A melasz, Műszaki és Mezőgazdasági Könyvkiadó, Budapest 1980
(2) *Honig P.:* Principles of Sugar Technology, Elsevier Publ. Amsterdam– New-York, 1963.
(3) *Honig P.:* Proc. Ann. Conv. Sugar Tech-Assoc. India, 1961. p. 80.
(4) *James, A. M. and Lawrence:* ISSCT, 1965. p. 1691–1700.
(5) *Gromkovskii, A. J.:* Sakhar Prom. *39*, (5) 360, 1965.
(6) *Graham, W. S.:* South African Sugar Journal, 35 1966.
(7) *Schneider, F. and Emmerich, A.:* Compt. Rend. *13a*, Com. Fut. Tech. Sucr. 333, 1967.
(8) *Wilkes, R. and Jennings, P.:* Proc. Con. S. African Sugar Tech. 107, 1971.
(9) *Drago, J. and Delavierz, H.:* Zuckering, *22*, 498, 1972.
(10) *Brooks, P. C.:* Proc. Queensland Soc. Sugar Cane Tech., 229 1967.
(11) *Emmerich, A. and Finke, D.:* Zucker, *20*, 487, 1967.
(12) *Delavier, H. and Smolnik, H.:* Proceedings of XXXIX ATAC, Cuba, 1970.
(13) *Moritzagu, T. and Sloane, G. E.:* Ann. Rept. Hawaian Sugar Planters Assoc. Exp. Sta. 132, 1970.
(14) *Devillers, P. and Phelizot, R.:* Sucr. Franc, *112*, 431, 1971.
(15) *Bhattacharryya, S.– Boger, D. V.– Holmes, A. L. and Tin, G.:* Proc. QSSCT 209, 1972.
(16) *Kolarov, K. and Garcell, L.:* Cuba– Azucar, Jul– Sept, 1974.
(17) *Spencer, G. L.:* Manual del Azucar de cana 4 Edicion, Barcelona, 1973.
(18) *Browne and Zerban:* Physical and chemical Methods of Sugar Analysis, Third. Ed. 1941.
(19) *Pequeno Perez S.:* Agroquimica, 1968, Ciencia, Tecnica, Cuba.
(20) *Norniella, G. and Hernandez, A.:* Analisis Quimico, ISPJAE, 1975., Cuba

KUBAI MELASZOK VISZKOZITÁSA

Raul Boué MONTERO

A kubai cukorgyárakból származó nagyszámú curkornádmelasz minta vizsgálata alapján megállapítható, hogy a melaszok a 40 – 80 °C tartományban pszeudoplasztikus testként jellemezhetők.

A „Rheotest" rotációs viszkoziméteren mért adatok és a kolloid anyag tartalom között nem sikerült egyértelmű összefüggést találni.

A melaszok viszkozitását alapvetően a hőmérséklet és a szárazanyag tartalom befolyásolja.

ВЯЗКОСТЬ КУБИНСКОЙ МЕЛАССЫ

Раул Боуе Монтеро

На основании исследования большого количества образцов тростниковой сахарной мелассы происходяших из кубинских сахарных заводов установили, что меласу в пределах температуры 40 – 80 °C можно считать псеудоластическим тестом.

Между данным измерений на ротационном вискозиметре «Реотест» и содержанием коллоидных веществ не удалось найти однозначную зависимость.

На вязкость мелассы в основном оказывает влияние температура и содержание сухого вещества.