



REFRACTIVE, CODOUNIS, KIRKWOOD AND TABOURET INDICES IN THE EVALUATION OF SELECTED COLOMBIAN HONEYS

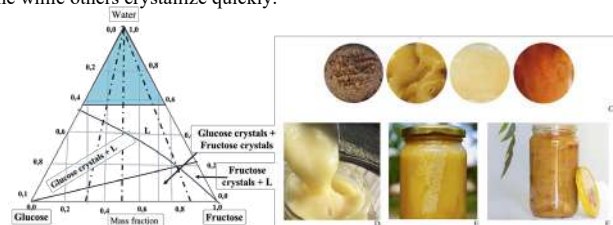
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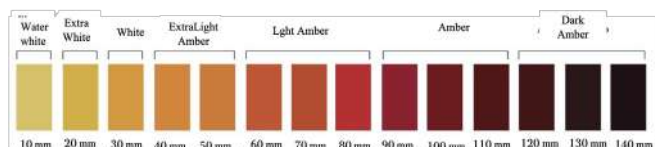
REMARKS

Honey is essentially a solution of reducing sugars, usually in a state of supersaturation with respect to glucose at room temperature, since glucosa-being one of its major constituents has relatively low solubility. Crystallization in Honey represent a supersaturated compounds containing glucose and fructose. Glucose has lower solubility than fructose, so it tends to precipitate out of solution and form crystals. Not all honeys crystallize at the same rate: some remain liquid for a long time while others crystallize quickly.

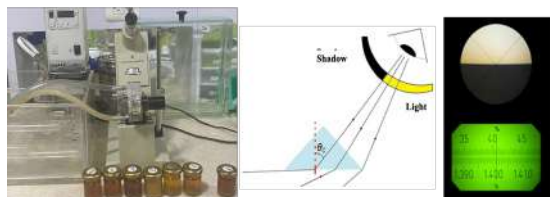


Glucose (91 g/100 mL) crystallizes easily in honey, while the higher solubility of fructose (380 g/100 mL) helps it remain liquid. Sucrose (~200 g/100 mL) and maltose (165 g/100 mL) show intermediate behavior. Honey's botanical origin defines its composition, sensory profile, and therapeutic value, making thorough characterization essential. During storage, honey may crystallize fully, partially, or remain in a metastable state. The Codounis Index is an early metric developed to quantify the crystallization tendency of honey, providing one of the first attempts to express crystallization risk as a single numerical

Color, expressed on Pfund scale, is nly used as a discriminant parameter for the classification of honey categorizing honey into white, extra light amber, light amber, amber, and dark amber. Color is strongly influenced by botanical origin, mineral content, and phenolic compounds, making it a valuable indicator in honey differentiation and quality control.



Honey's refractive index (RI) at 20 °C usually falls between 1.474 and 1.504, depending on water content. As water increases, (RI) decreases, parameter is temperature dependent: $n_{20} = n_T + 0.00023 \cdot (T - 20)$, here n_{20} is refractive index corrected to 20 °C; n_T RI measured at temperature $T(^{\circ}\text{C})$.

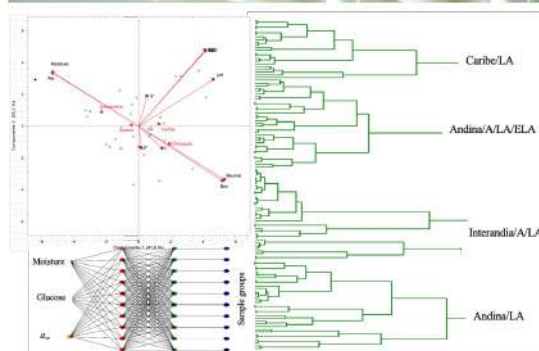


Kirkwood's Index relates honey's botanical origin to electrical conductivity, pH, and color. EC reflects mineral content and correlates with polyphenols and antioxidant activity. Differentiation relies mainly on dissolved solids (Xs), reducing sugars (Xr), and pH. (KI) values below 73.1 is required for a sample to be classified as honeydew honey: $IK = 1,4Xr - 8,3pH - 12,3X$.

METHODS

Honey samples from various Colombian biogeographical regions and altitudes were analyzed. Color was classified using the Pfund scale and supported by refractive index, Tabouret, and Kirkwood indices. Differentiation was based mainly on fixed solids (Xs), reducing sugars (Xr), and pH.

RESULTS



Color	Pfund (mm)	RI (n_D , 20 °C)	
Water White	10	1.4830-1.4835	The refractive index of amber honeys is around 1.4845, while white honeys show values of 1.4838. The highest values correspond to light amber (LA), and the lowest were found in samples from the lower montane very humid forest (<i>lm-VHF</i>) 1.4923) and tropical dry forest (<i>td-F</i>): 1.4831.
Extra White	8-17	1.4835-1.4838	
White	17-34	1.4838-1.4842	
Extra Light	34-50	1.4842-1.4845	
Light Amber	50-85	1.4845-1.4850	
Amber	85-114	1.4850-1.4855	
Dark Amber	> 114	1.4855-1.486	

Honey crystallization is mainly influenced by its glucose and water content. When glucose levels are lower, the higher water availability enhances fructose dissolution but limits glucose incorporation into the solution, accelerating crystal formation. Conversely, high glucose combined with reduced moisture increases the granulation index. Crystal formation begins in a section of the honey, which may cover part of it, and in some cases, the process is accompanied

Tabouret's Index (n =2)			Color honey		
Zona de vida	A	W	DA	ELA	LA
lm-HF	9,10		9,65		9,38
pm-HF					9,42
th-F	8,70		8,35	7,5	9,25
lm-VHF				11,2	
pm-VH	10,3		9,51		7,97
td-VDF	7,98		9,32		8,13
lm-DF	8,70			10,0	10,2
td-F	8,50	11,1		8,97	8,90



Color	n	IK
A	31	71,0
DA	17	61,9
ELA	26	76,5
LA	58	75,8
W	4	79,9

The Index (IK), used as a classification parameter for honeydew, establishes a threshold value of 73.1 to identify honeydew honeys. Samples exceeding this limit are classified as honeydew. Typically, amber (A) and dark amber (DA) honeys exhibit these characteristics.

In tropical regions, honeys generally present higher moisture content due to the prevailing humid climate, a factor that directly affects viscosity and increases susceptibility to fermentation, thereby emphasizing the need for careful post-harvest handling and storage practices.

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Honey is fundamentally a solution of reducing sugars and is typically supersaturated with respect to glucose at room temperature, with lower solubility compared to glucose, which is the least soluble of the major components. The botanical origin of honey determines its chemical composition, organoleptic characteristics, and therapeutic properties. Honey often undergoes total or partial crystallization during storage periods, and some that do not crystallize remain in a metastable state. Changes in external factors, such as pressure or temperature, lead to the crystallization of the product. In this study, honey samples from different biogeographical environments in Colombia, collected at various altitudes, were evaluated. The color tones of the samples were grouped according to their origin, and classification estimates were made considering the respective refractive indices, Tabouret index, and Kirkwood index. The physicochemical parameters considered in the differentiation of these samples are primarily based on the contribution of fixed solids (Xs), reducing sugar levels (Xr), and the pH of the honey. The Kirkwood Index (KI) should be less than 73.1 for a sample to be considered honeydew. The granulation of honey is a natural phenomenon and depends on temperature, viscosity, and moisture levels. The Tabouret Index is commonly used in this context. Crystal formation begins in a section of the honey, which may cover part of it, and in some cases, the process is accompanied by the formation of spots and color changes. Fructose inhibits granulation by increasing the solubility of glucose in the honey, and maltose also has an inhibitory effect on this process. The tendency to granulate can be estimated by considering the water activity values and the Glucose/Water (G/H) ratio through the Tabouret Index (TI). Electrical conductivity (EC), pH, and color are the most commonly used parameters to determine the botanical origin of honey.