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Hunter versus CIE color measurement systems for analysis of milk-based beverages

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ABSTRACT

The objective of our work was to determine the differences in sensitivity of Hunter and International Commission on Illumination (CIE) methods at 2 different viewer angles (2 and 10 degrees) for measurement of whiteness, red/green, and blue/yellow color of milk-based beverages over a range of composition. Sixty combinations of milk-based beverages were formulated (2 replicates) with a range of fat level from 0.2 to 2%, true protein level from 3 to 5%, and casein as a percent of true protein from 5 to 80% to provide a wide range of milk-based beverage color. In addition, commercial skim, 1 and 2% fat high-temperature, short-time pasteurized fluid milks were analyzed. All beverage formulations were HTST pasteurized and cooled to 4°C before analysis. Color measurement viewer angle (2 versus 10 degree) had very little effect on objective color measures of milk-based beverages with a wide range of composition for either the Hunter or CIE color measurement system. Temperature (4, 20, and 50°C) of color measurement had a large effect on the results of color measurement in both the Hunter and CIE measurement systems. The effect of milk beverage temperature on color measurement results was the largest for skim milk and the least for 2% fat milk. This highlights the need for proper control of beverage serving temperature for sensory panel analysis of milk-based beverages with very low fat content and for control of milk temperature when doing objective color analysis for quality control in manufacture of milk-based beverages. The Hunter system of color measurement was more sensitive to differences in whiteness among milk-based beverages than the CIE system, whereas the CIE system was much more sensitive to differences in yellowness among milk-based beverages. There was little difference between the Hunter and CIE system in sensitivity to green/red color of milk-based beverages. In defining milk-based beverage product specifications for objective color measures for dairy product manufacturers, the viewer angle, color measurement system (CIE vs. Hunter), and sample measurement temperature should be specified along with type of illuminant.
Key words: color, milk, whiteness

INTRODUCTION

Color influences sensory perception and consumer preference of food products. A review by Clydesdale (1993) summarized studies focusing on color effects on taste thresholds, sweetness perception, pleasantness, salt perception, preference, and acceptability and perception of food and beverages in an elderly population. More recently, Chung (2009) studied consumer preference of full-fat, low-fat, and lactose-free milk pasteurized by UHT or low-temperature, long-time, and milks with higher whiteness and lower yellowness were perceived as having higher flavor intensity. McCarthy et al. (2017) determined visual and tasting difference thresholds for fat in fluid milk followed by paired preference testing with follow-up interviews and reported better color or color/whiteness was an important reason that skim milk, 2% fat milk, and whole milk drinkers all preferred higher fat level milks. Further, consumers were less sensitive to differences in fat concentration when correlated appearance differences were removed, confirming the role of appearance and color on sensory properties of fluid milk.

Phillips et al. (1995a), Phillips and Barbano (1997), and Misawa et al. (2016) concluded that objective measurement of whiteness showed correlations with several appearance, texture, and flavor sensory descriptors for low-fat milks. Phillips et al. (1995a) found that increasing milk fat level (0.06 to 2.0%) increased L-value (whiteness) and decreased a-value (greenness to redness) and b-value (blueness to yellowness) of milk, which were well correlated with perceived color of low-fat milk by sensory analysis with trained panels. Phillips et al. (1995a) also reported using trained panelists that milk appearance largely influenced the perceived

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mouthfeel of milk. This confirmed the results from Pangborn et al. (1985) that visual cues were important for milk differentiation based on fat level. McCarthy et al. (2017) confirmed the importance of color with consumer panelists. Addition of nonfat dry milk (0 to 2%) to low-fat milk showed no difference in color and sensory perception of milk (Phillips et al., 1995b), whereas the addition of titanium dioxide made skim milk whiter and increased the trained panel sensory scores for milk appearance descriptors (Phillips and Barbano, 1997). Increasing true protein (**TP**) level (Quiñones et al., 1997, 1998) and casein as a percentage of true protein (Misawa et al., 2016) increased whiteness of low-fat milks and caused the sensory perception of these low fat milks to be more similar to higher fat level milks.

Hunter (L, a, b) and International Commission on Illumination (**CIE**) L*, a*, and b* color measurement systems or color space are primarily used in food, textile, and pharmacy industries. Both color measurement systems were developed based on the CIE (x, y, z) 1931 system to generate a more uniform color space for color measurement with specific calculation equations for L/L*, a/a*, and b/b* (Hunter and Harold, 1987). The primary difference in these 2 color system is the Hunter (L, a, b) equations use the square root of CIE (x, y, z) for L, a, b calculation, whereas the CIE (L*, a*, and b*) equations use the cubic root (Hunter and Harold, 1987). However, both color systems are not ideally uniform. The Hunter (L, a, b) system is more sensitive in measuring blueness, whereas the CIE (L*, a*, b*) system is more sensitive in measuring yellowness and dark colors (CIE, 1978; Hunter and Harold, 1987; Hunter Associates Laboratory, 2012). Today, the L/L*, a/a*, and b/b* values can all be obtained easily from colorimeter software and the most repeatable and sensitive metrics can be selected for use by an analyst. However, it is not always clear if the Hunter or CIE color measurement system is the best for analysis of milk-based beverages. The objective of our work was to determine the differences in sensitivity of Hunter and CIE methods at 2 different viewer angles for measurement of whiteness, red/green, and blue/yellow color of milk-based beverages over a range of composition.

MATERIALS AND METHODS

Experimental Design

Population of Beverage Formulations and Commercial Milks. Beverage formulations were based on a complete balanced 3 factor (fat, TP, and casein as a percentage of TP) design with 3 fat levels (0.2, 1.0, and 2.0%), 4 TP levels (3.00, 3.67, 4.34, and 5.00%) within each fat level and 5 casein as a percentage of true protein (**CN%TP**) levels (5, 25, 50, 75, and 80%) within each protein level as shown in Table 1. The formulation, sensory, and analytical work was done in 1 wk for each fat level and the formulation, processing, and analysis were replicated for all the treatments within each fat level in a second week, for a total of 6 wk of processing. Color of commercial skim, 1 and 2% fat milks was also evaluated using the same analysis methods. There were 2 replicates of the commercial milk at all 3 fat levels for color analysis by both methods.

Table 1. Formulation design for 0.2, 1.0, and 2.0% fat level milk protein beverages with variation in casein as a percentage of true protein (CN%TP) of 5, 25, 50, 75, and 80% at true protein (TP) levels of 3.00, 3.67, 4.34, and 5.00% within each fat level

Fat (%)	TP (%) 3.00	3.67	4.34	5.00	
0.2	5	5	5	5	CN%TP
	25	25	25	25	CN%TP
	50	50	50	50	CN%TP
	75	75	75	75	CN%TP
	80	80	80	80	CN%TP
1.0	5	5	5	5	CN%TP
	25	25	25	25	CN%TP
	50	50	50	50	CN%TP
	75	75	75	75	CN%TP
	80	80	80	80	CN%TP
2.0	5	5	5	5	CN%TP
	25	25	25	25	CN%TP
	50	50	50	50	CN%TP
	75	75	75	75	CN%TP
	80	80	80	80	CN%TP

Comparison of Hunter Versus CIE Color Metrics. The goal of this data collection was to determine the effect of viewer angle (2 vs. 10 degrees) and color measurement system (Hunter vs. CIE) for evaluation of milk-based beverage color and was determined by the following comparison. For a color term, within each color metrics, the value differences observed at 2- and 10-degree viewer angles in response to changes in beverage composition were compared, whereas within each viewer angles, the value differences obtained from Hunter and CIE systems in response to changes in beverage compositions were compared to determine if the color differences among treatments were different under different objective color measurement approaches.

Effect of Processing and Composition Parameters on Milk Beverage Color. Thermal processing causes protein-protein interactions (Corredig and Dalgleish, 1999; Singh, 2004; Donato and Guyomarc'h, 2009) and thermal degradation of milk proteins (Van Boekel, 1998; Meltretter et al., 2007) and lactose (O'Brien, 2009), and these degradation products and interactions may influence color and viscosity of milk-