Colorimetry of Dairy Products

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Abstract

Reflectance colorimetry was investigated to measure the colour of whole (WMP) and skim milk (SMP) powders, infant formulas (IF), an adult nutritional product (ANP), unsalted (USB) and salted (SB) butters. The colorimeter gave precise results and was cost effective, illustrating the benefits of the adoption of a colorimeter rather than the current practice of using reference charts and powders. New Zealand dairy products are yellower compared with other dairy products because of their relatively high naturally occurring β-carotene content.

1. Introduction

Food colour is measured by colour chart comparison, visible near infrared spectroscopy, computer-based image analysis, reflectance spectroscopy, transmittance spectroscopy and colorimetry (Dufossé & Galaup, 2010; Pathare, Opara, & Al-Said, 2013). Advantages of colorimetry are (i) it is performed in uniform light, (ii) it is not reliant on human subjective measurements, (iii) it is portable and cheap, (iv) samples can be solid or an opaque liquid, and (v) it is not reliant on storage of references that may vary with time.

The purpose of this study was to examine whether colorimetry could replace colour charts and reference powder comparisons and to apply this technique to the routine sensory evaluation of dairy

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products, including adult nutritional powders and stage three infant formulas not previously reported. For adoption to be successful, the colorimeter needs to be easy to use and cost effective and give precise results comparable to the current methods.

2. Materials and methods

The colour of skim milk, whole milk, infant formulas, adult nutritional powders, winter and early spring manufactured salted and unsalted butter were measured using a Konica Minolta CR400 colorimeter (ThermoFisher, Auckland, New Zealand). Daily calibration used the reference white ceramic tile. A Konica Minolta CR A50 (50 × 9 mm glass-topped colorimetry cell) was used for powders, and this was packed with 10 g of the powder. The surface was smoothed using a rule. Between powder sample measurements, the cell was emptied and any residual was removed using brushes.

A fresh flat surface on refrigerated butter was cut with a knife and before being covered with a layer of transparent polyethylene film. To calibrate for butter the reference tile was covered with a single layer of the film.

To assess the repeatability and intermediate precision of the colorimeter, a single batch of adult nutritional powder (stored in gas-flushed and re-sealable foil bags) was used. For repeatability, the powder was measured in duplicate 15 times, while for intermediate precision it was measured in duplicate on 23 days over 2.5 months.

Colorimetry ranges for 60 different batches of skim, whole and different nutritional milk powders, salted and unsalted butters were measured. Butter colour reference tiles were also measured.

The reference powder method is set at point two, using a five-point scale, where good powder is within one point of the reference. Acceptable butter must be the same or be less coloured than the US Department of Agriculture (USDA) medium light reference.

3. Results and discussion

Results are reported in Lab colour space where L* is lightness from black (0) to white (100), a* is green (−) to red (+) and b* is blue (−) to yellow (+) (ISO/CIE, 2008). The results demonstrate good repeatability and intermediate precision of the colorimeter (Table 1). The range and precision for different products are shown in Table 2.

Green colour in milk is due to the riboflavin content (Nozière et al., 2006). Processing can form Maillard browning reaction products increasing redness and this, plus changes in particle size affecting light diffusion, changes lightness (Grigioni et al., 2007; Pugliese et al., 2017). Previous literature measurements of L*a*b* scores are given in Table 3. Powders in this study were darker than powders previously reported.

New Zealand whole milk powders and butters have high yellowness scores from β-carotene in grass feed (Dufossé, Fernández-López, Galaup, & Pérez-Alvarez, 2015). Skim milk powder is usually darker than whole milk because of light diffusion, but because of the yellowness whole milk powder was darker (Pugliese et al., 2017).

Infant formulas were generally darker and less green than the milk powders or European infant formulas. Change in colour was probably due to the extra minerals and oils ingredients used to manufacture infant formula. All butters were within the light to medium range compared to USDA butter colour reference tiles reported in Table 4. The colorimeter was more cost effective based on the 5 min allowed for chart and powder comparisons whereas colorimetry measurements took less than 1 min.

4. Conclusions

Colorimetry is a feasible alternative to using reference colour charts or powder references as it gives precise results and is more cost effective. New Zealand dairy products differ in colour from similar international products previously reported, because of their significant yellow colour from the high naturally occurring β-carotene content.

CRediT author statement

Rehana Ponnal: validation, formal analysis, investigation, data curation. Jackie Wood: conceptualization, methodology, validation, formal analysis, data curation, writing original draft, writing and editing, supervision, resources, project administration, visualisation. Brendon Gill: software, writing original draft, writing and editing, visualisation. Carlos Bergonia: conceptualization, methodology, resources, project administration, supervision. Wendy Longstaff: conceptualization, methodology, resources, supervision. Valerie Slabbert: resources, project administration. Lissa Bainbridge-Smith: supervision and project administration. Robert Crawford: conceptualization, methodology, writing and editing, supervision, project administration.

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Table 1.USDA butter colour guide measurements

Variable	Mean single day	RSD_r (%)	R	Mean 2.5 months	RSD_{iR} (%)
L*	91.08	0.16	0.40 91.00 0.35	91.00	0.35
a*	−6.85	−1.39	−1.39	−6.68	a−1.51
b*	17.55	1.73	0.84	17.38	1.34

[a] For mean single day, n = 15 duplicate pairs; for mean 2.5 months, n = 23 duplicate pairs.

Abbreviations: RSD_r, repeatability relative standard deviation of n pairs of duplicates; R, repeatability limit (= standard deviation × t_∞ × √2); RSD_{iR}, intermediate repeatability relative standard deviation of n pairs of duplicates.

Table 2. Results for the different product types[a]

Sample	Number pairs	L* Mean	Range	RSD_r (%)	R	RSD_{ir} (%)	a* Mean	Range	RSD_r (%)	R	RSD_{ir} (%)	b* Mean	Range	RSD_r (%)	R	RSD_{ir} (%)
WMP	124/62	89.48	87.41 to 91.66	0.39	0.96	1.05	−7.94	−6.73 to −8.74	−0.50	0.11	−6.87	22.00	19.21 to 23.90	0.57	0.34	6.39
Ref WMP	2/0	90.91	91.52 to 90.29				−6.90	−7.11 to −6.96				22.69	22.95 to 22.43			
SMP	136/68	91.44	89.35 to 92.77	0.39	1.00	0.95	−7.44	−6.88 to −9.30	−1.02	0.21	−7.75	16.63	14.43 to 21.55	1.24	0.57	9.81
Ref SMP	12/6	91.81	90.38 to 92.69				−7.16	−6.91 to −7.52				15.76	15.05 to 17.30			
IFS1	164/82	87.45	84.45 to 89.63	0.32	0.77	1.62	−4.39	−0.44 to −5.21	−18.12	2.20	−10.29	18.00	14.44 to 21.27	0.97	0.48	14.17
Ref IFS1	14/7	87.24	85.98 to 89.22				−4.39	−3.92 to −4.68				18.88	15.12 to 20.56			
IFS2	120/60	86.90	85.21 to 88.83	0.40	0.90	1.07	−4.88	−0.45 to −6.32	−7.48	1.01	−17.26	19.20	16.18 to 21.21	0.83	0.44	8.26
Ref IFS2	14/7	86.91	85.23 to 88.51				−5.00	−4.27 to −6.00				19.24	17.22 to 21.21			
IFS3	120/60	88.36	86.75 to 89.87	0.36	0.87	0.82	−6.56	−5.11 to −7.77	−0.67	0.12	−15.79	20.20	16.48 to 23.83	0.64	0.36	9.60
Ref IFS3	18/9	88.86	87.60 to 89.87				−5.93	−5.30 to −7.42				18.52	16.66 to 20.23			
ANP	120/60	90.64	87.99 to 91.61	0.36	0.90	0.64	−6.87	−5.53 to −16.59	−13.35	2.54	−13.62	17.09	15.91 to 18.00	1.11	0.52	2.23
Ref ANP	14/7	90.52	87.99 to 91.50				−6.49	−5.53 to −7.03				16.88	16.33 to 17.63			
USB	120/60	87.82	82.93 to 90.67	0.70	1.70	1.52	−4.00	−3.23 to −4.73	−4.03	0.45	−6.93	30.37	26.81 to 33.41	2.04	1.71	4.65
SB	120/60	85.76	81.89 to 89.77	0.88	2.10	1.28	−3.99	−2.57 to −5.51	−5.25	0.58	−7.39	32.07	25.53–35.06	2.58	2.29	3.90

[a] Mean and range of n replicates shown

Abbreviations: RSD_r, repeatability relative standard deviation of n pairs of duplicates; R, repeatability limit (= standard deviation × t_{∞} × √2); RSD_{iR}, intermediate repeatability relative standard deviation of n pairs of duplicates

Table 3. Literature colorimetric results for milk powders, infant formula and butters[a]

Product	Location	L*	a*	b*	References
SMP	USA	79.05	0.78	7.36	Koc, Heinemann, & Ziegler (2003)
SMP	Austria	94.9	−1.7	11.3	Kneifel, Ulberth, & Schaffer (1992)
SMP	New Zealand	93.0	−2.2	16.4	
SMP	USA	92.5	−2.6	18.3	
WMP	Europe	95.6	−3.6	19.8	
WMP		95.96	−3.05	9.56	Nanua, McGregor, & Godbert (2000)
SMP		96.94 ± 0.56	−2.32 ± 0.14	11.12 ± 1.32	Pugliese et al. (2017)
WMP		96.01 ± 0.54	−1.74 ± 0.31	14.45 ± 0.55	
WMP, autumny	Argentina	92.63 ± 0.44	−0.48 ± 0.11	19.61 ± 0.57	Grigorini et al. (2007)
WMP, autumnz		93.38 ± 0.08	−0.73 ± 0.10	18.62 ± 0.42	
WMP, wintery		93.09 ± 0.17	−0.53 ± 0.13	20.30 ± 0.66	
WMP, winterz		93.19 ± 0.30	−0.65 ± 0.17	18.55 ± 0.54	
WMP, springy		92.56 ± 0.35	−0.65 ± 0.20	21.11 ± 0.61	
WMP, spring		93.22 ± 0.18	−0.50 ± 0.19	19.12 ± 0.66	
WMP, summery		92.19 ± 0.32	−0.74 ± 0.10	20.37 ± 0.58	
WMP, summerz		92.90 ± 0.48	−0.85 ± 0.16	20.05 ± 0.92	
WMP	United Arab Emirates	95.37	−0.01	12.67	Sulieman, Elamin, Elkhalifa, & Laleye (2014)
Infant formula, stage 1	Europe	92.34	−0.25	12.31	Ferrer, Alegría, Farre, Clemente, & Calvo (2005)
Infant formula, stage 1		90.70	−0.25	14.78	
Butter 10 °C, summer		63.2	3.9	31.1	Kneifel et al. (1992)
Butter 10 °C, winter		70.8	4.7	28.3	

[a] Abbreviations are: SMP, skim milk powder; WMP, whole milk powder. Heat treatments indicated as: y, indirect; z, direct

Table 4. USDA butter colour guide measurements

Plate colour description	L*	a*	b*
Very light (VL)	92.03	−2.44	22.43
Light (L)	90.91	−2.39	25.14
Medium light (ML)	89.19	−2.26	31.30
Medium (M)	87.86	−1.38	36.27
Medium high (MH)	86.53	0.27	37.19
High (H)	84.97	2.67	38.95
Very high (VH)	77.54	9.10	44.22