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Tristimulus colour reflectance measurement of milk and dairy products

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Summary — A tristimulus reflectance technique was applied to the objective assessment of the colour of milk and dairy products. A variety of milk and dairy products (liquid milk, cultured products, cheese, butter, milk powder) was characterized based on the L^*, a^*, b^* (CIE-LAB) colour parameters. The b^* value was not suitable for estimating the β-carotene content of butter, whereas storage defects (non-enzymatic browning reactions) of whey powder could be monitored using this parameter.

colour / milk product / reflectance colorimetry / tristimulus technique

Résumé — Méthode tristimulus (réflexion colorimétrique) pour la mesure de la couleur du lait et des produits laitiers. *La technique de réflexion tristimulus a été appliquée à la mesure objective de la couleur d'un certain nombre de laits et de produits laitiers du commerce. Parmi ceux-ci, on trouve des liquides, des produits fermentés frais tels que yaourts, diverses sortes de fromages, des beurres d'été et d'hiver et des poudres de lait, caractérisés par leurs valeurs* L^*, a^* *et* b^* *selon la CIE. La composante jaune* b^* *s'est révélée inadéquate à estimer la teneur en β-carotène du beurre, mais permet de suivre les altérations subies par une poudre de lactosérum en cours de stockage (brunissement non enzymatique).*

couleur / produit laitier / photométrie de réflexion / méthode tristimulus

INTRODUCTION

In general, colour and shape are the major properties that give objects their individual characters. As far as foods are concerned, other sensations such as smell, taste and textural attributes contribute to the overall quality of these products. Nevertheless, in many cases food colour is the first criterion to be perceived by the consumer. It is well known that the repeated recognition of a particular brand of a food commodity largely depends on its typical colour. Thus, in the food industry the assessment of the colour of foods and its components has become an integral part of total quality control. Since reliable methodology for the objective measurement of colour has been developed, this technique has found widespread use in many food sectors. For instance, intrumental assessment of the colour of meat and meat products (Stolle and Paulick, 1990), egg yolk (McCready *et al,* 1973) fruits and vegetables (Kader and Morris, 1978; Wainwright and Hughes, 1989), sweets and chocolate (Ugrinovits, 1987; Kneifel *et al,* 1990) and coffee (Francis and Clydesdale, 1975) has been described. Several reports concerning milk and dairy products can also be found in the literature (Bosset *et al,* 1977, 1979, 1983a,b, 1986; Kammerlehner and Kessler, 1979; Desarzens *et al,* 1983; Desarzens, 1988; Giangiacomo and Messina, 1988, 1989; Kneifel *et al,* 1992).

The purpose of this paper was to demonstrate the potential inherent in objective colour measurement and to present a survey of the colour of different milk products as estimated by a tristimulus reflectance technique.

MATERIALS AND METHODS

Sample materials

A variety of milk and dairy products was purchased from local retail outlets. Whey and milk powder samples were provided by different Austrian plants. For storage experiments, whey powders with different water content were prepared by conditioning the products in an atmosphere of defined humidity provided by cabinets containing defined salt solutions. Retail lard was used as "reference material" (matrix) for colour measurements of butter. β-Carotene was purchased from Sigma Chemicals (St Louis, USA).

Heat treatments of milk

Screw-capped glass tubes containing 20-ml portions of raw milk (4.1% fat) were immersed in a boiling water-bath until the required heating temperature was reached. Thereafter, the samples were held at 70, 80 and 90 °C for 1 and 5 min respectively in thermostated water-baths. An oil-bath was used for heat-treatment at 100 and 120 °C using the same time conditions. Samples were cooled in an ice-bath after heating.

Colour measurement

A Microcolor tristimulus colorimeter (Dr Bruno Lange GmbH, Berlin, Germany) was used for colour testing. Calibration was performed using the Dr Lange "White-standard" LZM 076 (standard tristimulus values: X = 69.0; Y = 73.5; Z = 77.0) as specified by the manufacturer. The measuring principle of this apparatus is based on a d/8° optical structure, 10° standard observer, D 65 standard illuminant. A xenon flash lamp was the light source. Each sample was tested in 4 replicates. Results were expressed using the L^*, a^*, b^*-system according to CIE-LAB (Commission Internationale de l'Éclairage, 1971). In this system, L^* defines the position of the sample on the dark–light axis, a^* on the green-red axis, and b^* on the blue-yellow axis.

Liquid and semi-solid products were filled to the engraved mark of a "liquid sample" quartz cuvette, and subsequently covered with a PTFE piston. Care was taken not to include air bubbles in the liquid. Fruit yogurts were stirred with a spoon and subsequently poured through a 1-mm sieve to remove larger particles before measurement. Powdered products were transferred into the "powder sample" quartz cuvette. The filled cuvette was then tapped slightly on a solid support in order to ensure a homogeneous sample distribution. Both types of cuvette were placed on the head of the Microcolor measuring unit and covered with a lid before starting the measuring cycle. In the case of solid samples like cheese, the measuring unit was placed directly onto the specimen which had been freshly cut from the cheese sample. All samples were measured at 20 ± 1 °C after an equilibration time of at least 1 h (Burton, 1956).

Other physical and chemical parameters

Dry matter of powdered products was determined according to FIL-IDF standard (International Dairy Federation, 1964). Sieve fractions of milk powder were collected as described by Haugaard-Sorensen *et al* (1978). Total hydroxymethylfurfural (HMF) concentration was determined according to the spectrophotometric method of Keeney and Bassette (1959). The extent of homogenization was estimated as outlined by Schneider and Roeder (1979). Carotene content of butter fat was determined according to Pardun (1969). Melted butter oil was decolorized with charcoal, following the methodology proposed by Schaap and Rutten (1974).

RESULTS AND DISCUSSION

Precision of colour measurement

The precision of the colour reflectance method was determined by repeatedly measuring pasteurized whole milk (3.6% fat). The within-run relative standard deviation (RSD) ($N = 10$) was 0.06% for the L^* value, 2.99% for b^*, and 0.65% for a^*. The between-run RSD ($N = 10$) was 1.21%, 3.11% and 1.44%, respectively.

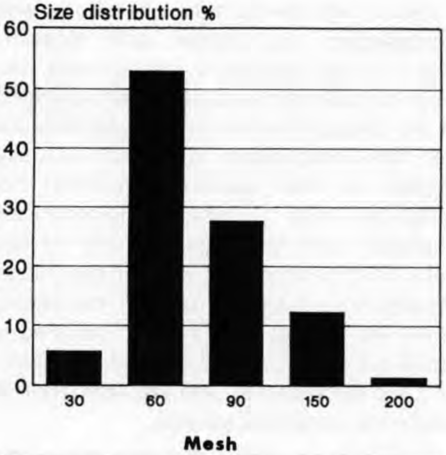
Colour parameters of milk and dairy products

A characterization of the colour of different dairy products is given in table I. As can be seen from these data, liquid and cultured milk products tested had slight 'green' and 'yellow' components. The values found for pasteurized milk are partly different from those reported by Giangiacomo and Messina (1988) ($L^* = 88.2$, $a^* = -4.35$, $b^* = 5.40$) and by Bosset and Blanc (1978) ($L = 95.5$, $a = -2.0$, $b = 12.6$). The observed differences between our results and those reported by Bosset and Blanc (1978) were obviously due to the fact that they used the Hunter-*L,a,b* system. Compared to retail liquid milk (3.6% fat, homogenized), the b^* value of set-style yogurt increased by 1.3 units. As demonstrated by Giangiacomo and Messina (1989), this difference is caused by the acidification and coagulation process. Most of the cheese types can be characterized as exhibiting slight 'red' and pronounced 'yellow' colour components. The L^* values of the liquid and cultured milks indicated a high degree of whiteness and gave a rather consistent pattern, ranging from 81.7 to 87.5. Skimmed products tended to be lower in L^* than their corresponding full-fat products (producing a higher degree of light scattering). The colour parameters of fresh and feta-type cheese closely resembled those data obtained with liquid products. On the other hand, ripened cheese varieties showed a marked variation in colour values. It has been shown previously (Bosset *et al*, 1977) that several parameters, *eg* texture (holes and cracks), surface properties, oil exudation, sample thickness and slicing technique can influence the results of colour measurements on cheese samples. Mainly due to the typical colour of the additives, the colour parameters of fruit yogurts varied as expected to a great extent.

The colour parameters of full-cream milk powders differed from those of the skimmed milk powders (table I). The relative magnitude of this difference was mostly pronounced with respect to the b^* value. However, it should be taken into consideration that in the CIE-LAB system the Y^* parameter is used for the computation of L^*, a^* and b^*, meaning that all parameters are interrelated. Obviously, the powder colour is influenced by the fat content *via* the liposoluble β-carotene. The colour of powdered milk products may also be influenced by technological parameters and by the geographical as well as climatic conditions of milk production (table I). It is further evident from the colour data given in figure 1 that there were no marked differences in the L^* and a^* values of the sieve

Table I. Typical colour parameters of different milk products (mean values of at least 3 different replicate samples); *L**: dark (0), light (100); *a**: green (–), red (+); *b**: blue (–), yellow (+).
Composantes typiques de la couleur de produits laitiers différents (valeur moyenne d'au moins 3 échantillons mesurés en triple); L*: *(foncé) (0), clair (100);* a* *vert (–), rouge (+);* b* *bleu (–), jaune (+).*

Product type	*Fat content (%)*	L*	a*	b*
Pasteurized milk	< 0.1	81.7	–4.8	4.1
	3.6	86.1	–2.1	7.8
	4.5	86.2	–1.7	7.5
UHT milk	2.5	86.0	–2.0	7.9
Cream	36.0	88.1	–0.2	8.8
Coffee cream	10.0	86.9	–0.5	8.6
Cultured buttermilk	0.1	86.5	–2.6	6.9
Cultured milk	3.6	87.5	–1.5	6.5
Yogurt (set-style)	1.0	85.9	–2.5	8.8
	3.6	86.6	–1.9	9.1
Yogurt with fruits				
apricot	3.2	82.3	1.3	10.7
strawberry	3.2	77.0	9.1	4.9
blueberry	3.2	52.9	20.6	–7.3
raspberry	3.2	67.8	13.1	2.4
Yogurt dessert product				
vanilla	7.0	83.7	0.9	11.8
coffee	7.0	66.5	5.3	18.7
Fresh soft cheese	< 1.0	85.7	–0.9	10.4
	10.0	86.1	–0.9	10.4
	20.0	85.6	–0.3	10.6
	40.0	85.0	1.3	10.7
Gervais	65.0	85.9	1.1	12.0
Processed cheese	55.0	91.0	3.0	18.6
Camembert (surface)	45.0	95.7	0.1	5.2
(interior)		85.6	3.3	26.9
(surface)	60.0	94.6	0.5	5.9
(interior)		86.8	3.2	27.7
Brie (surface)	60.0	95.9	0.2	4.1
(interior)		90.2	2.7	26.5
Feta cheese	45.0	93.5	–1.1	11.0
Roquefort	50.0	92.8	–1.4	14.5
Tilsit cheese	35.0	77.2	3.1	28.8
Tilsit Swiss type	45.0	79.9	3.1	24.1
	25.0	72.9	4.0	27.6
Edam cheese	45.0	79.8	4.2	32.2
Gouda cheese	30.0	82.6	3.6	27.1
Swiss type cheese	45.0	72.7	0.6	20.9
Appenzell type cheese	45.0	71.9	2.2	25.5
Full-cream milk powder	25.0	95.6	–3.6	19.8
Skimmed milk powder				
(Austrian origin)	1.0	94.9	–1.7	11.3
(American origin)	1.0	92.5	–2.6	18.3
(New Zealand origin)	1.0	93.0	–2.2	16.4



L*	93,6	95,3	95,8	96,3	96,5
a*	-3,7	-3,5	-3,5	-3,3	-3,6
b*	20,8	20,1	19,3	18	19,8

Fig 1. Particle size distribution and colour parameters L^*, a^* and b^* of full-cream milk powder.
Distribution des particules et des composantes L*, a* *et* b* *de la couleur de la poudre de lait entier.*

fractions collected from full-cream milk powder. Only the b^* values differed to a certain extent. This observation is also in agreement with the findings of Bosset *et al* (1979).

Colour of butter

Results of colour measurements on butter samples are listed in table II. Colour differences between summer and winter butter were apparent and mainly due to differing β-carotene contents. Moreover, it is evident from the data that the L^*, a^*, b^* parameters were strongly influenced by the sample temperature. This effect is obviously caused by the temperature-dependent extent of fat crystallization (solid/liquid ratio). In the case of colour measurements on butter, it is therefore particularly necessary to perform the tests under defined temperature–time conditions to obtain a stable crystal modification.

In another series of experiments, an attempt was made to estimate the β-carotene content of butter based on the b^* values as an indicator for the yellow colour. Different amounts of β-carotene were added to a decolorized butter oil, and for reference purposes also to lard, which is known to be completely colorless. The b^* values measured are graphically presented in figure 2. Correlation coefficients (regression lines) calculated were 0.95 ($y = 3.020 + 2.010x$; $N = 6$) for the butter oil, and 0.98 ($y = 2.626 + 13.126x$; $N = 5$) for

Table II. Colour parameters of butter samples at different temperatures.
Composantes de la couleur des échantillons de beurre mesurés à différentes températures.

Butter type	*Sample temperature (%)*	L*	a*	b*
Summer butter	10	63.2	3.9	31.1
	16	61.8	3.0	30.6
	18	59.9	2.5	30.5
	22	57.1	2.5	30.4
Winter butter	10	70.8	4.7	28.3
	16	65.6	3.7	29.8
	18	63.8	3.4	29.7
	22	61.3	2.8	29.6

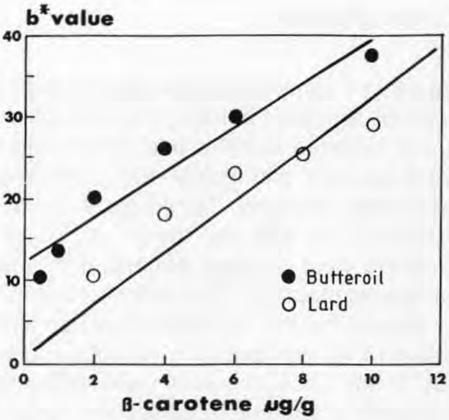


Fig 2. Relationship between β-carotene content and b^* values of butter oil and lard, after addition of known amounts of β-carotene.
Rapport entre la teneur en β-carotène et les valeurs b* *de la matière grasse liquide du beurre et du saindoux enrichis en β-carotène.*

the lard samples. Although a close correlation was observed between β-carotene concentrations and b^* values, an accurate estimation of the β-carotene content was not possible based on b^* value measurement. The deviations of the chemically determined β-carotene content from the results obtained by colour measurements may be due to the varying crystal structure of the products as well as to the dependence of b^* on other colour parameters (*eg* L^*). A similar divergence is evident from the results reported by Desarzens *et al* (1983) who were unable to find constant relationships between the vitamin B_2 contents and the *L,a,b* parameters of milk samples exposed to light for different time periods.

Changes of colour during processing and storage of milk products

The formation of coloured products in the course of heating of milk or milk concentrates to high temperatures has been well documented (*eg* Horak and Kessler, 1981). Using laboratory experiments, we were not able to detect significant changes in the colour of non-homogenized milk under time-temperature conditions usually applied for milk pasteurization within the range of 70–90 °C (table III). Pronounced changes could be registered only on severe heat treatment of milk in conditions resembling autoclaving or UHT treatment. However, Bosset *et al* (1979) indicated a small but significant increase of the Hunter-*L,a,b* components with the temperature applied to homogenized milk.

It has been shown that non-enzymatic browning reactions also occur during prolonged storage of dried milk products

Table III. Colour parameters of liquid milk heated at different time–temperature conditions.
Composantes de la couleur des laits chauffés a température et à durée contrôlées.

Heating conditions	L*	a*	b*	*µmol HMF/l*
70 °C				
1 min	79.4	–7.5	4.8	3.2
5 min	79.6	–7.6	5.6	3.1
80 °C				
1 min	79.0	–7.2	4.7	3.1
5 min	79.5	–7.4	5.6	3.3
90 °C				
1 min	78.9	–7.4	4.3	3.0
5 min	80.1	–7.5	5.7	3.5
100 °C				
1 min	79.9	–7.4	5.0	3.2
5 min	80.7	–7.3	5.6	5.2
120 °C				
1 min	80.3	–7.4	5.1	4.3
5 min	81.5	–5.8	6.9	17.1
20 min	81.5	–5.4	7.2	58.8

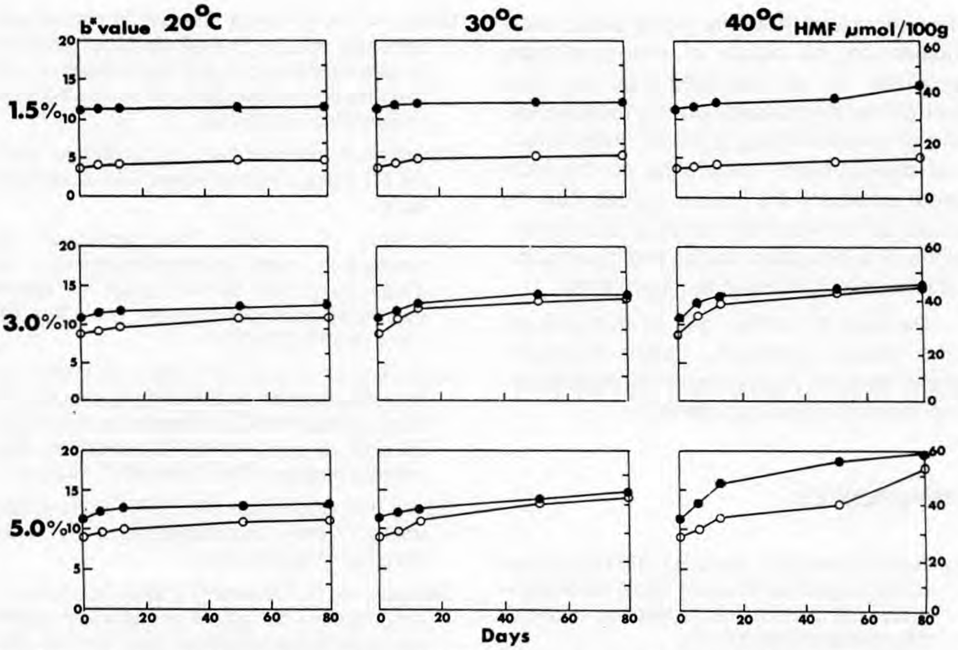


Fig 3. Development of browning reations and HMF during storage of whey powder of different water contents and at different temperatures. Open symbols: HMF values; closed symbols. b^* values.
Apparition du brunissement et de HMF pendant le stockage du sérum en poudre à teneur en eau et à température contrôlées. Symboles ouverts : HMF; symboles fermés : b*.

(Renner, 1988; Kneifel, 1989). Hitherto, the HMF value has mainly been used to describe these alterations. To demonstrate the relationship between powder coloration and HMF content, whey powder samples were stored at different temperatures (20, 30, 40 °C) and sampled periodically (fig 3). As the water content of the product influences the extent and the velocity of Maillard reactions, this parameter was adjusted to 1.5, 3.5 and 5.0% (w/w). The b^* value proved to be the most suitable indicator for the detection of changes in colour. As can be seen from these graphs, browning reactions of whey powders were pronounced at high temperatures and water contents, respectively. For example, the HMF values of samples with a moisture of 1.5, 3.5 and 5.0% which were stored at 30 °C increased to 148%, 160%, and 162% of their initial values. By contrast, the corresponding b^* values increased to 108%, 124% and 132%. Although the HMF value was generally more sensitive in detecting these alterations, reflectance colorimetry was a more rapid and simple means for the assessment of storage defects in whey powder.

CONCLUSIONS

Tristimulus colour reflectance measurement is a tool which can be utilized to obtain additional objective and well-defined physical data on milk and dairy products.

This technique not only yields basic information on the colour of milk and dairy products, but also enables a precise control of the food quality during manufacturing of selected dairy foods or during product development. Depending on the local legal situation, the colour values can be used as a basis for carrying out corrections of a product's colour (*eg* by addition of permitted food dyes or β-carotene).

Particularly in the case of fruit yogurts and dessert products, colour measurement may be of assistance in standardizing the desired colour intensity.

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