Can We Produce Images According to Our Tastes?

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Abstract In this paper, it was investigated whether the food packaging could be produced according to consumer expectations of the food tastes. Orange juice packaging was chosen as an example in this study to develop a model in relation between reproduced images and customer expectation. This model can predict the juice colour to the expectations of sourness, sweetness, bitterness, flavour strength and freshness. The experimental results suggested that the relationships can be modelled by the concept of colour difference formula, for which CIELAB formula was modified for the purpose to relate visual and taste perceptions. The models were robust, explaining at least 72% of the data behaviour.

Key words Fruit juice; Expectations; Colour appearance; Colour tolerance

根据口味复制食品包装图像

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摘要 本研究提出可以依据消费者对食品口味的预期生产食品包装，并以橙汁外包装为例，建立了复制图像与消费者预期口味的关系模型。此模型可以通过果汁包装物的颜色预测果汁的酸度、甜度、苦度、风味强度以及新鲜程度。实验结果表明：可以利用色差公式的概念来建立关系模型，通过优化 CIELAB 公式来建立视觉响应与味觉响应间的关系。72%以上的数据验证了该模型的可靠性。

关键词 果汁；预测；色貌；颜色容差

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0 Introduction

Colour appearance of food delivers the initial impression of the food itself to the customers. Customers' expectations of the food, such as flavour, tastes and quality, then are evoked from visual perception. These expectations play a vital role in making decisions of purchasing[1]. This is why seeking an appropriate food colour and controlling colours are always the major tasks in food industry.

For decades, researchers seek to link food colour and sensory characteristics either in the perceived levels or expected levels[2-8]. In general, they suggested that vivid colours tended to arouse stronger tastes or flavours than pale colours. People tended to prefer the liquid colours that matched with their memory (e. g. cranberry juice drink with vivid red colours). However, few of studies proposed a full view of the relationship between colours and sensory characteristics for a specific liquid food. Such a view would comprise a map of the intensity of sensory characteristics plotted on a colour

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space such as CIELAB[9-11]. With such a map, one can illustrate how intensity varies with changes of location in colour space. This study was aimed to develop a model to correlate between liquid colours and the intensity of sensory characteristics in the expected levels.

This research was intended to answer the question on whether food packaging can be printed according to consumer expectations of the food tastes.

1 Methods

The aim of this study was achieved by conducting a psychophysical experiment using semantic differential on a colour - calibrated CRT monitor by human observers, i. e. a 21 - inch SONY Trinitron Multiscan 20SE CRT display was used. The semantic differential is a technique to measure pepole's reactions to stimulus words or concepts in terms of ratings on bipolar scales defined with contrasting adjectives at each end.

Fifteen participants, seven males and eight females, aged from 22 to 36 years with an average of 25, were asked to visually assess stimuli shown on the display and to provide their psychological responses using the bipolar scales. The bipolar scales have five sensory characteristics, they are: sourness (Not sour at all - Extremely sour), sweetness (Not sweet at all - Extremely sweet), bitterness (Not bitter at all - Extremely bitter), flavour strength (Weak - Strong) and freshness (Stale - Fresh). Each of these scales was presented in terms of seven categories.

A total of 174 samples in terms of images were assessed by the participants. They were rendered from an image of an existing juice product. As shown in Fig. 1, the image of the juice product on the left was captured using a Canon EOS 350D camera. The juice product was placed against a uniform mid - grey background and was illuminated by a D_{65} simulator in a VeriVide viewing cabinet. The image on the right shows an example of the stimuli. This image was the modification of the original image on the left. The layout of all stimuli were identical except juice colours. As shown in

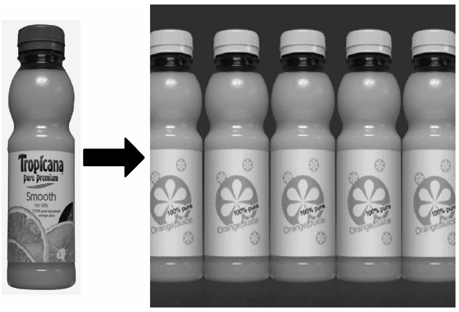
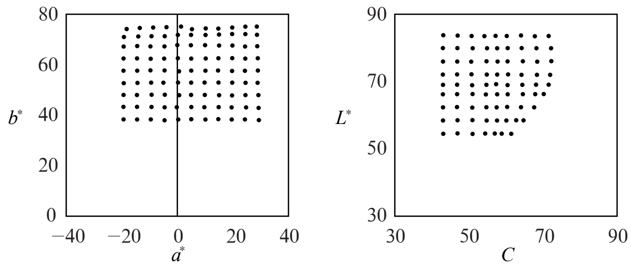


Fig. 1 Experimental stimulus on the right was designed according to the existing juice product on the left
图1 根据左边现有果汁产品设计右边实验产品



a. 98 equal-lightness juice colours b. 76 equal-hue juice colours

Fig. 2 174 selected juice colours
图2 174个选定的果汁颜色

Fig. 2a, the 174 juice colours were systematically selected in CIELAB colour space. Among these 98 were selected along the axes of a^* (redness - greenness) and b^* (yellowness - blueness) on the $a^* - b^*$ plane with a 5 - unit interval from the original juice colour, which had values of L^*, C and h were 69, 56 and 89°, respectively. The original juice colour was determined by measuring some orange juices in the viewing cabinet using a Minolta CS - 1000 spectroradiometer. The ranges of colour rendering were determined in a pilot study involving manipulation of the colour on the monitor screen until the image no longer looked like orange juice. The same approach was also used to select the other 76 juice colours along the axes of L^* (lightness) and C (chroma) on the $L^* - C$ plane (see Fig. 2b).

2 Results and Discussion

The consistency of behavioural data was examined via the tests of inter - observer and intra - observer agreements. The former represents whether an observer's experimental results agree with the majority (i. e. mean scores). The latter represents whether an observer's repeated assessments agree well, or whether this observer's results were consistent. Both inter – and intra – observer agreements were determined by *Root Mean Square* (*RMS*). As a result, the difference between individual observers' responses and the responses of the majority was smaller than 1.5 categories on the basis of the 7 – category measurement scale. The difference between repeated assessments was smaller than 1 category. The results showed a high level of observer consistency and the data were valid for further analysis.

According to the examination of the relationships between colour attributes and the behavioural data, we found that the intensities of the five expectations varied in accordance with the changes of colour perceptions. Taking freshness as an example as shown in Fig. 3, its intensities varied with lightness, chroma and hue of juice colours. In general, a colourful juice colour with its lightness around 70 and hue angle around 90° appeared fresher than other colours. For the other four expectations, greenish juice colours elicited greater sourness and bitterness responses. Darker juice colours were more likely to be expected to be bitter, and redder and yellower juice colours were expected to have stronger and sweeter flavour.

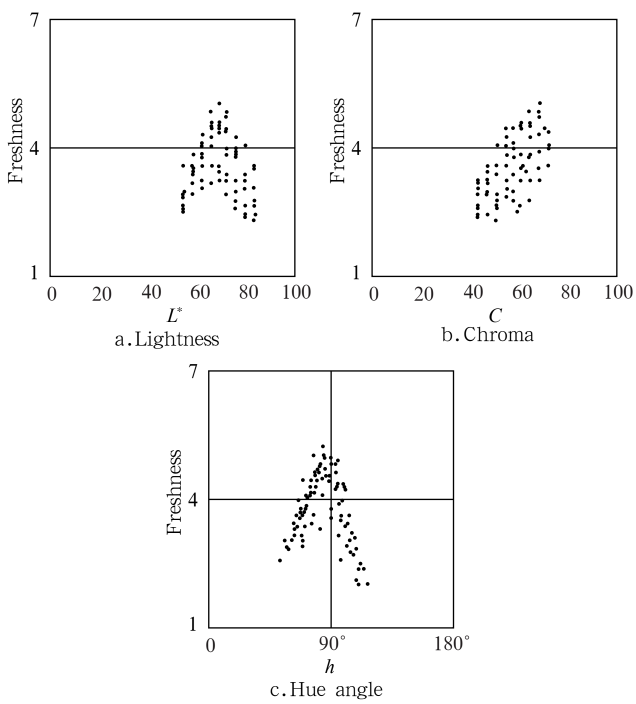


Fig. 3 Scatter plots of freshness against the three colour attributes
图3 各新鲜度颜色三属性散点图

The above results suggest that each taste expectation could be modelled as a function of colour attributes. After trials on various models, a simple metric based on colour difference equation could explain well the relationship between the taste expectation and colour attributes, i. e. the change of taste expectation against a colour centre in CIELAB colour space. As shown in Fig. 4, the size of the bubbles represented the intensity of freshness. The intensity of freshness gradually increased toward a colour centre. This feature of the relationship between juice colour and expectations was modelled using the formula ΔE_{OJ} (Eq. 1), which was a modification of CIELAB colour difference formula.

$$\Delta E_{OJ} = \sqrt{(L^* - L_0^*)^2 + \frac{(C - C_0)^2}{k_c} + \frac{\Delta H^{*2}}{k_h}} \qquad \text{Eq. 1}$$

where $\Delta H^* = 2\sqrt{C \cdot C_0} \cdot \sin\left(\frac{h - h_0}{2}\right)$

and L^*, C and h are CIELAB colour attributes of a given colour; L_0^*, C_0, and h_0 are CIELAB colour attributes of the colour centre; k_c and k_h are two coefficients, optimised from the experimental data.

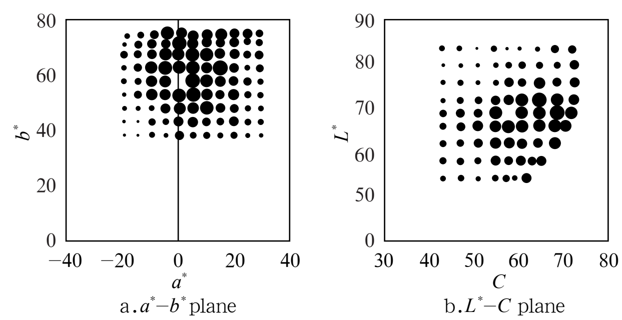


Fig. 4 Bubble chart of freshness in a^*-b^* plane and in L^*-C plane
图4 各新鲜度在 a^*-b^* 空间和 L^*-C 空间的泡状分布图

Tab. 1 summarised the values of colour centres, k_c and k_h of ΔE_{OJ} for each of the five expectations. The values of R^2 represented the performance of ΔE_{OJ} for explaining the experimental results. The corresponding predictived performance (i. e. coefficient of determination, R^2, a higher of this value means more convincing the results, or a higher correlation between two sets of parameters) was also given in the table. Overall, ΔE_{OJ} explained over 80% of the experimental data except for sourness (72%). Fig. 5 showed the colour centres of the five expectations of tastes in a^*-b^* plane.

Open dots and close dots represented the centre of the weakest and the strongest intensities, respectively. For the expectations of sweetness and freshness, the colour centres give the sweetest and the freshest expectations, respectively. For sourness, bitterness and flavour strength, the colour centres gave the least sour, least bitter and the weakest flavour.

Tab. 1 CIELAB values of colour centres associated with the five expectations
表 1 5 种预期口味对应的 CIELAB 色空间内的色度值

Colour centre	L_0^*	C_0	h_0	k_c	k_h	R^2
Sourness	74	58	69	0.03	0.01	0.72
Sweetness	69	69	71	3.59	3.88	0.86
Bitterness	83	65	73	2.01	1.00	0.80
Flavour strength	89	34	163	1.21	1.16	0.83
Freshness	68	66	83	4.39	3.54	0.82

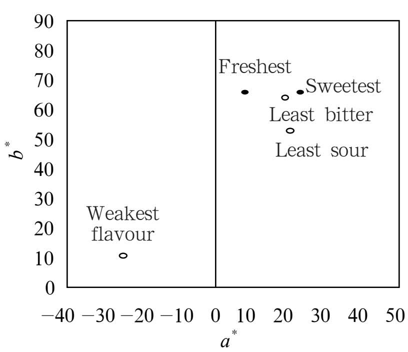


Fig. 5 Colour centres of the five expectations of tastes
图 5 5 种预期的口味对应颜色在色空间中的位置

3 Conclusions

This study successfully achieved its goal to control the colours of an image to meet the customer's expectation on taste. A model was developed to describe the relationships between liquid colours and the intensity of sensory characteristics in the expected levels. An empirical experiment using semantic differential was carried out. The results showed that redness of juice colours strongly influenced the expectation of sourness and bitterness. In addition, sweetness and flavour strength were found to be related to each other as they showed similar results in both $a^* - b^*$ and $L^* - C$ planes. Overall, the intensity of each expectation gradually increased or decreased toward a colour centre. This feature could be captured using a modified CIELAB colour difference formula, i.e. ΔE_{0J}.

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