Experimental RGB and CIE L*a*b* colour space analysis and comparison for fruits and vegetables

[1]Hitesh Singh Waskale, [2]Mahesh Ganpat Bhong
[1,2]Department of Mechanical Engineering,
[1]Indira College of Engineering and Management, Pune, India

Abstract – Colour indicates the freshness and dryness of fruits and vegetables. Many colour space are available to measure the approximate colour value of natural food items. This experiment deals with comparison of colour reproduce by RGB colour space value and CIE L*a*b* colour space value. Fruits and vegetables sample of different colour shades where selected and their high definition photos were taken and converted into RGB colour space and CIE L*a*b* colour space using MATLAB 2015a V2.1 and reproducing the colour in Adobe Photoshop Creative Studio 6 V13.0.1. The colour reproduced shows that colour obtain by RGB colour value appears more balanced in hue and saturation as compare to those colour obtain by CIE L*a*b* colour space value. But it is more convenient to use CIE L*a*b* colour space because its colour coordinates can explain the level of saturation and hue in numerical way.

Index Terms – RGB, CIE L*a*b*, MATLAB, Fruits and vegetables.

I. INTRODUCTION

Colour is the brains reaction to a specific visual incentive. We can approximately describe colour by measuring its spectral power distribution which leads to a large degree of redundancy. The reason for this could be the eye's retina samples colour using only three broad bands, which is red, green and blue light [1]. The signals from these colour sensitive cells (cones), together with those from the rods (sensitive to intensity only), are combined in the brain to give several different "sensations" of the colour. These sensations have been defined by the CIE [2] and Hunt's book [3].

A colour space is a method by which we can specify, create and visualize colour. As for humans, colour is defined by its attributes of brightness, hue and colorfulness. A colour is usually specified using three co-ordinates, or parameters which describe the position of the colour within the colour space being used. They do not tell us what the colour is, that depends on what colour space is being used. Many different colour space been evolved along the period of time such as CIE XYZ (1931), CIE YUV (1960), CIE YU'V', CIE L*u*v*, CIE L*a*b*, RGB, CMY (K), HSL, etc. The RGB color space is used for specifying colors. It is an additive colour system based on tri-chromatic theory. RGB is easy to implement but non–linear with visual perception. This model specifies the intensity of red, green, and blue on a scale of 0 to 255, with 0 (zero) indicating the minimum intensity. The settings of the three colors are converted to a single integer value [4].

$$RGB\ value = R + (G * 256) + (B * 256 * 256) \tag{1}$$

CIE Luv and CIE Lab are CIE based colour model. They are nearly linear with visual perception, or at least as close as any colour space is expected to sensibly get. Since they are based on the CIE system of colour measurement, which is itself based on human vision, CIE Lab and CIE Luv are device independent but suffer from being quite unintuitive despite the L parameter having a good correlation with perceived lightness. The CIE XYZ system is at the root of all colorimetry. It is defined such that all visible colours can be defined using only positive values, and, the Y value is luminance. Consequently, the colours of the XYZ primaries themselves are not visible. The chromaticity diagram is highly non-linear, in that a vector of unit magnitude representing the difference between two chromaticities is not uniformly visible. A colour defined in this system is referred to as Yxy. A third co-ordinate, z, can also be defined but is redundant since x + y + z = 1 for all colours.

$$x = \frac{X}{(X+Y+Z)} \tag{2}$$

$$y = \frac{Y}{(X+Y+Z)} \tag{3}$$

The CIE L*a*b* colour space is based directly on CIE XYZ and is another attempt to linearize the perceptibility of unit vector colour differences. It is non-linear, and the conversions are reversible. Colouring information is referred to the colour of the white point of the system, subscript n. The non-linear relationships for L* a* and b* are the same as for CIE LUV and are intended to mimic the logarithmic response of the eye.

$$L^* = \begin{cases} 166\left(\frac{Y}{Y_n}\right)^{1/3} - 16 & \left(if\ \frac{Y}{Y_n} > 0.008856\right. \\ 903.3\left(\frac{Y}{Y_n}\right) & \left(if\ \frac{Y}{Y_n} \leq 0.008856\right. \end{cases} \tag{4}$$

$$a^* = 500 * \left(f(X/X_n) - f(Y/Y_n)\right) \tag{5}$$

$$b^* = 200 * \left(f(Y/Y_n) - f(Z/Z_n)\right) \tag{6}$$

$$f(t) = \begin{cases} t^{1/3} & (if\ t > 0.008856) \\ 7.787 * t + (16/116) & (if\ t \leq 0.008856) \end{cases} \quad (7)$$

Here, L* scales from 0 to 100 and the polar parameters closely match the visual experience of colours.

$$C^* = (a^{*2} + b^{*2})^{0.5} \quad (8)$$

$$h_{ab} = \arctan\left(\frac{b^*}{a^*}\right) \quad (9)$$

Defined by the Commission Internationale de l'Eclairage (CIE) [5], the L*a*b* color space was modeled after a color-opponent theory stating that two colors cannot be red and green at the same time or yellow and blue at the same time [6]. L* indicates lightness, a* is the red/green coordinate, and b* is the yellow/blue coordinate.

$$\Delta L^* = (L^*\ sample\ 1 - L^*\ Sample\ 2) = difference\ in\ lightness\ and\ darkness \quad ((+) = lighter,\ (-) = darker) \quad (10)$$

$$\Delta a^* = (a^*\ sample\ 1 - a^*\ Sample\ 2) = difference\ in\ red\ and\ green \quad ((+) = redder,\ (-) = greener) \quad (11)$$

$$\Delta b^* = (b^*\ sample\ 1 - b^*\ Sample\ 2) = difference\ in\ yellow\ and\ blue \quad ((+) = yellower,\ (-) = bluer) \quad (12)$$

Here, ΔL*, Δa* and Δb* are the difference between the colour coordinate L*, a* and b* of two different testing sample. Deltas for L* (ΔL*), a* (Δa*) and b* (Δb*) may be positive (+) or negative (-). The total colour difference between all three coordinate of two testing sample is represented by Delta E (ΔE*), which is always positive.

$$\Delta E^* = Total\ colour\ difference = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})^{1/2} \quad (13)$$

This experiment aims to compare colour reproduce by RGB colour space value and CIE L*a*b* colour space value by comparing three sample of different fruits and vegetables. The similarity or dissimilarities among the colour regenerated was compared on the basis of hue, colour saturation and colour appearance closer to true colour.

II. EXPERIMENTAL SETUP

Comparison was experimented on three set of fruits and vegetables. Each set comprise of Capsicum, Jalapeno chili, Lemon, Sweet lime, Apple, Sapodilla, Tomato and Strawberry. High definition micro photo of resolution 3264x2448 with 72 dpi of items was taken using Apple iPhone 5C having 8 megapixel Sony sensor 1/32 inch, 1.4 micron sensor pixels and f /2.4 lens [7]. Constant light intensity was maintain during photography. The high definition photo was imported to MATLAB 2015a V2.1 where RGB and CIE L*a*b* colour value was obtain by using image processing tool. The RGB and CIE L*a*b* colour value was reproduce in Adobe Photoshop Creative Studio 6 V13.0.1 [8].

Table 1 RGB colour space value for different set of fruits and vegetables

Sr. No.	Eatables	Set 1			Set 2			Set 3		
		R	G	B	R	G	B	R	G	B
1	Tomato	132	47	27	138	65	28	121	41	27
2	Capsicum	53	81	15	52	78	11	60	90	21
3	Jalapeno chili	50	73	26	56	82	25	67	93	24
4	Sapodilla	97	75	54	98	75	55	99	76	53
5	Lemon	167	154	56	144	125	39	147	134	47
6	Apple	127	44	45	83	20	27	103	27	35
7	Strawberry	115	43	48	132	45	47	114	33	36
8	Sweet lime	158	114	16	150	120	25	153	115	16

Table 2 CIE L*a*b* colour space value for different set of fruits and vegetables

Sr. No.	Eatables	Set 1			Set 2			Set 3		
		L*	a*	b*	L*	a*	b*	L*	a*	b*
1	Tomato	32	35	31	36	28	35	29	33	27
2	Capsicum	31	-21	32	29	-20	33	34	-22	33
3	Jalapeno chili	28	-17	24	31	-20	29	36	-21	34
4	Sapodilla	33	6	16	33	6	15	34	6	17
5	Lemon	63	-7	50	52	-2	46	55	-5	49
6	Apple	31	35	18	17	29	12	23	34	14
7	Strawberry	28	31	13	32	36	19	26	35	18
8	Sweet lime	51	9	53	51	2	51	50	6	53

Table 3 CIE L*a*b* colour space: Total colour difference between different sets of fruits and vegetables

Sr. No.	Eatables	Set 1 differ from Set 2				Set 2 differ from Set 3				Set 3 differ from Set 1			
		ΔL*	Δa*	Δb*	ΔE*	ΔL*	Δa*	Δb*	ΔE*	ΔL*	Δa*	Δb*	ΔE*
1	Tomato	-4	7	-4	9	7	-5	8	11.7	-3	-2	-4	5.4
2	Capsicum	2	-1	-1	2.4	-5	2	0	5.4	3	-1	1	3.3
3	Jalapeno chili	-3	3	-5	6.6	-5	1	-5	7.1	8	-4	10	13.4
4	Sapodilla	0	0	1	1	-1	0	-2	2.2	1	0	1	1.4

5	**Lemon**	11	-5	4	12.7	-3	3	-3	5.2	-8	2	-1	8.3
6	**Apple**	14	6	6	16.4	-6	-5	-2	8.1	-8	-1	-4	9
7	**Strawberry**	-4	-5	-6	8.8	6	1	1	6.2	-2	4	5	6.7
8	**Sweet lime**	0	7	2	7.3	1	-4	-2	4.6	-1	-3	0	3.2

III. RESULTS AND DISCUSSION

Figure 1 shows colour regenerated for Tomato by RGB and CIE L*a*b* colour space value. For all three set of Tomato, the hue and saturation value was high for colour regenerated by RGB colour space as compare to the colour regenerated by CIE L*a*b* colour space. Also the colour regenerated by RGB colour space value seems to be more natural and real. Similar result was obtain for Capsicum, Jalapeno chili, Sapodilla, Lemon, Apple, Strawberry and Sweet lime in Fig. [2-8] where the colour regenerated by RGB colour space value seem to be more vivid, high in saturation and hue value.

Comparison of colour regenerated by RGB colour space value and CIE L*a*b* colour space value was easily distinguish by visual inspection but the degree by which the saturation and hue was changing was hard to compare by R, G and B value in RGB colour space. Whereas in CIE L*a*b* colour space (Table 2), the change in saturation was easy identified by change in L* value, a* signifies red/green colour variation and b* signifies yellow/blue colour variation. It was numerically easy to compare the change in shade in given colour sample in CIE L*a*b* colour space as compare to RGB colour space.

The total colour variation (ΔE*) from set 1 to set 2 achieved by CIE L*a*b* colour space coordinates (Table 3) was 9, 2.4, 6.6, 1, 12.7, 16.4, 8.8 and 7.3 for Tomato, Capsicum, Jalapeno chili, Sapodilla, Lemon, Apple, Strawberry and Sweet lime respectively which was not possible to predict by RGB colour space coordinates (Table 1). Visual inspection give sense of colour difference between the colour regenerated by both RGB colour space coordinates and CIE L*a*b* colour space coordinates but it is difficult to state the amount by which the colour shade differ from set to set of fruits and vegetables by referring RGB colour space coordinate. Whereas CIE L*a*b* colour space coordinates can predict the total colour variation among the set of fruits and vegetables by calculating the value ΔE*.

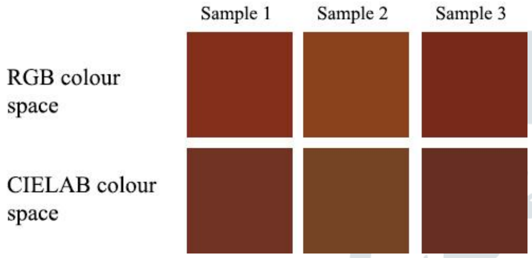

Figure 1 RGB and CIE L*a*b* colour comparison for Tomato

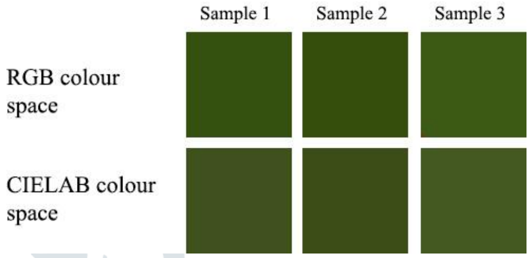

Figure 2 RGB and CIE L*a*b* colour comparison for Capsicum

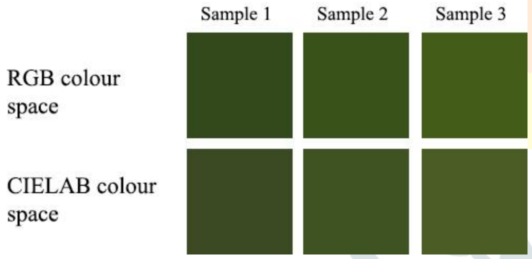

Figure 3 RGB and CIE L*a*b* colour comparison for Jalapeno chili

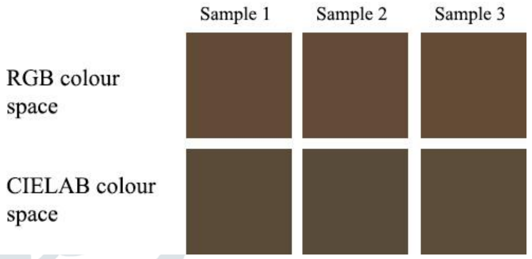

Figure 4 RGB and CIE L*a*b* colour comparison for Sapodilla

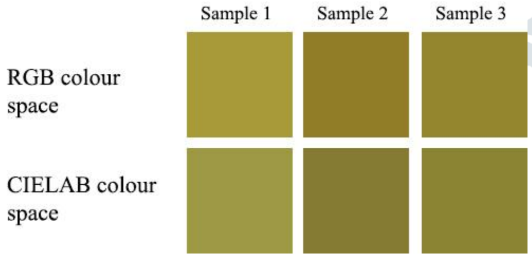

Figure 5 RGB and CIE L*a*b* colour comparison for Lemon

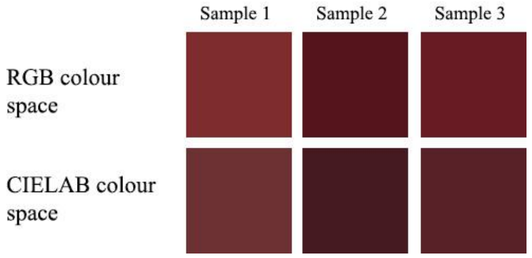

Figure 6 RGB and CIE L*a*b* colour comparison for Apple

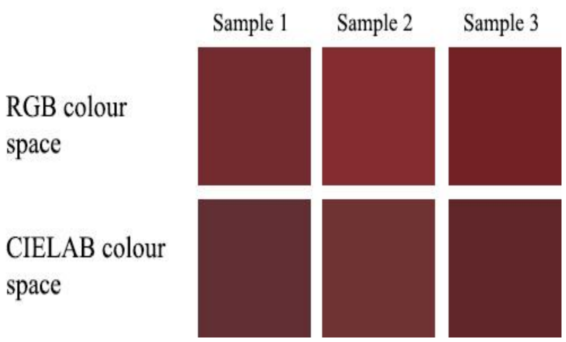

Figure 7 RGB and CIE L*a*b* colour comparison for Strawberry

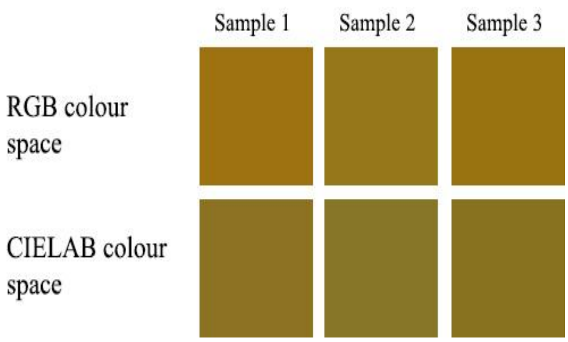

Figure 8 RGB and CIE L*a*b* colour comparison for Sweet Lime

IV. CONCLUSION

Colour regenerated by RGB colour space has good colour saturation and hue value as compare to the colour regenerated by CIE L*a*b* colour space. The coordinates of CIE L*a*b* colour space can state the lightness or darkness and particular colour domination over a given sample of tested fruits and vegetables which was not possible to express by the coordinates of RGB colour space. Total colour variation from set to set of tested fruits and vegetable was possible to predict only by CIE L*a*b* colour space coordinates. Overall using CIE L*a*b* was preferable to measure colour of fresh or dried fruits and vegetables, total colour variation of different sample of same fruits and vegetables and total colour change of processed eatable items.

REFERENCES

[1] A. Ford and A. Roberts, Colour Space Conversions, United Kingdom: BBC Research & Development, 1998.

[2] C. Oleari, "CIE 1924 Spectral Luminious Efficiency Function," in *Standard Colorimetry: Definitions, Algorithms and Software*, John Wiley & Sons, 2015, pp. 180-181.

[3] R. W. Hunt and M. R. Pointer, Measuring Colour, 4th Edition, John Wiley & Sons, 2011.

[4] "RGB Color Model," Microsoft Developer Network, November 2009. [Online]. Available: https://msdn.microsoft.com/en-us/library/dd355244.aspx. [Accessed 26 March 2017].

[5] "International Commission on Illumination," CIE, Babenbergerstraße 9/9A, A-1010 Vienna, Austria, [Online]. Available: http://www.cie.co.at/. [Accessed 26 March 2017].

[6] "Identifying Color Differences Using L*a*b* or L*C*H* Coordinates," Konica Minolta Sensing Americas, Inc., 2006. [Online]. Available: http://sensing.konicaminolta.us/2014/04/identifying-color-differences-using-l-a-b-or-l-c-h-coordinates/. [Accessed 26 March 2017].

[7] "iPhone 5C - Camera Image Quality," Time Inc. (UK) Ltd Technology Network, [Online]. Available: http://www.trustedreviews.com/iphone-5c-review-camera-image-quality-page-4. [Accessed 5 March 2017].

[8] "The Lab Color Mode in Photoshop," Adobe TechNote 310838, 1 April 2007. [Online]. Available: http://web.archive.org/web/20081207061220/http://kb.adobe.com/selfservice/viewContent.do?externalId=310838. [Accessed 5 March 2017].