A study on how food colour may determine the categorization of a dish: predicting meal appeal from colour combinations

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A person's preference to select or reject certain meals is influenced by several aspects, including colour. In this paper, we study the relevance of food colour for such preferences. To this end, a set of images of meals is processed by an automatic method that associates mood adjectives that capture such meal preferences. These adjectives are obtained by analyzing the colour palettes in the image, using a method based in Kobayashi's model of harmonic colour combinations. The paper also validates that the colour palettes calculated for each image are harmonic by developing a rating model to predict how much a user would like the colour palettes obtained. This rating is computed using a regression model based on the COLOURlovers dataset implemented to learn users' preferences. Finally, the adjectives associated automatically with images of dishes are validated by a survey which was responded by 178 people and demonstrates that the labels are adequate. The results obtained in this paper have applications in tourism marketing, to help in the design of marketing multimedia material, especially for promoting restaurants and gastronomic destinations.

Keywords: food adjectives, food characterisation, food colour, Kobayashi, Colour Image Scale, colour palette, colour rating, preferences, harmonic colours, survey, data mining, tourism, gastronomic destinations, regression model, preferences, mood.

1. Introduction

Thanks to social networks consumers can currently receive information regarding any restaurant using applications such as TripAdvisor, Yelp and TheFork. Potential costumers can view the best restaurants, together with their menus and dishes by means of photographs provided by restaurant owners and/or previous clients.

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All these elements allow consumers to obtain information in advance about the gastronomy on offer and to generate expectations regarding the restaurant's fare.

In addition, 88.2% of destination strategies use a gastronomic image to promote destinations,[1] which is probably due to the Food-service sector holding 56.7% of the value of the tourist industry.[2] According to several authors, destination images affect the behaviour of tourist decisions on destination choice and perception.[3–8] Furthermore, several authors divide image destinations into *cognitive* and *affective*.[9–11]

Local food could influence destination choice and perception of experience both before and after a trip.[12–14] According to Björk and Kauppinen-Räisänen,[15] the internet provides positive destination image for pre-travelling as a marketing strategy to provide a holistic travel experience. Furthermore, the most common channel for the gastronomic promotion of destinations is with official tourism websites that display the most typical local dishes.[15–18] On the official tourism website, information, photos, and graphics are provided that could create a gastronomic image.[16]

Food colour is part of the cognitive perception of food choice. Colour is an essential element in the food industry, including restaurants, food franchising businesses, and food advertisements.[19] Research shows that people perceive food as an object through their system of visual perception before tasting it, and predicting its taste, and making a decision about whether to buy or eat a food product.[20–23] Therefore, colour is sometimes the most decisive element as an indicator for the selection and evaluation of food. As Birren[24] memorably stated:

> *Colour is forever a part of our food, a visual element to which human eyes, minds, emotions and palates are sensitive. Perhaps through eons of time, man has come to build up strong and intuitive associations between what he sees and what he eats.*

Hence, the visual perception of the dishes is an important aspect because it is evoked by the position of food items on a plate, the colour, and the artistic aspect of dishes provided by the skills of the chef.[25] Furthermore, colours can be used in the dish to intensify the feeling of seasonality that they evoke.[26]

According to psychologists, a greater perceived sweetness can be achieved in foods by adding the colour red,[27] and the colour influence is so strong that it can change a consumer's experience. For example, some consumers smelled the aroma of a Bordeaux red wine when it was a white wine artificially coloured in the shade of dark red, which shows that even experts could be deceived by food colour.[28,29] Also, another study[30] revealed that the same strawberry mousse evoked a different sensation depending on the colour of the plate used to serve it. Diners reported that a strawberry mousse served on a white plate had a flavour that was 10% sweeter and 15% more flavourful than that served on a black plate. Therefore, the same way colour contrast (e.g. pink on white background vs. pink on black background) influences people's perception and affects colour naming,[31] it also may influence people's sensation of food.[30,32]

The ecological valence theory claims that colour preferences are an outcome of educational and cultural values and vary significantly for different object contexts, particularly in terms of lightness and chroma. Furthermore, colours evoke different affective experiences in people.[33,34] It is also known that cooked vegetables are less aesthetic than fresh vegetables, since raw foods lose their bright colours.[35] Moreover, according to Schifferstein *et al.*,[36] usually consumers use the colour of vegetables as a cue to identify the product through the prototypical colour (e.g., red for tomatoes, green for cucumbers, orange for carrots), but also to assess the safety, quality, and ripeness of the product, and to make inferences about its sensory properties.

The challenge in this paper is to assign adjectives to dishes taking into account their food colour. This challenge is intended to be faced in two ways: (i) automatically by computational methods; and (ii) asking people about their opinion. For that, Kobayashi's model, named *Colour Image Scale* is used, which demonstrated the semantic space of colours by assigning an adjective to harmonic combinations.[37]

On one side, Shigenobu Kobayashi, the founder of Nippon Colour and Design Research Institute Inc., developed a Hue and Tone System based on the Munsell Colour System (referring to the ISCC-NBS method of designating colour and a dictionary of colour names during the process) representing the entire world of colour in 130 colours which are systematically and psychologically representative, making them ideal for psychological research on colour.[38]

On the other side, *Colour harmony* is defined as (i) a set of colours that look good when seen together;[39] (ii) two or more colours seen in neighbouring areas producing a pleasing effect;[40] and (iii) two or more colours brought together to produce a satisfying affective response.[41]

The *Colour Image Scale* by Kobayashi[37] considers harmonic colour palettes that have been defined as sets of colours that hold a special internal relationship that provides a pleasant visual perception[42] because those are aesthetically pleasing to the human eye.[43] Thus it can be used to rate the users' pleasantness of a food based o its colour palette.

To the best of our knowledge, there are no studies in the literature that relate Kobayashi's harmonic palettes with food colour in images of dishes.

The aim of this paper is to relate food colour with adjectives that arise in people when they see them (i.e. *delicious, fresh, sweet, healthy,* etc.). To this end, an experiment with three steps is conducted: (i) an automatic method extracts the main Kobayashi's 3-colour-palette of a set of images of dishes and then it associates the Kobayashi's moods of the detected palettes to the image; (ii) a customised test is carried out with the same set of images in order to validate the results of the automatic method; (iii) in order to validate the harmony of the colour palettes, a rating method (based in a regression model) is developed to measure how much the palette would appeal people.

The rest of the paper is structured as follows. The methodology used is shown in Section 2. Section 3 describes the experimentation. Section 4 presents the results obtained. Section 5 provides a discussion and finally, future work is outlined.

2. Methodology

For the last four decades, Kobayashi's *Colour Image Scale* has been widely adopted throughout major industries in many eastern countries including Japan and Korea, as well as in Europe, in four application fields: fashion, interior design, product design, and visual media.[38]

Kobayashi's model, was developed to define how a single colour and harmonic combinations of colours affect people's moods. This model was derived through the use of multiple statistical analyses using a semantic differential method, following a set of psychological research studies[44] in which 130 basic colours and 1152 three-colour combinations were matched to 202 keywords (i.e., adjectives).

According to,[38] Kobayashi believed that colour names reflect the culture, lifestyle, and experiences of the people who use those names, and hypothesize that colour names express colour distinctions that are meaningful to people.

After a series of studies, Kobayashi created a system that: (i) maps each colour in a two-dimensional space based on the perceptual qualities of warmth/coldness and hardness/softness; (ii) assigns labels related to mood to particular areas in this space (for example, *happy* and *vigorous*); (iii) groups labels (i.e., areas in the perceptual space) that are related to different lifestyles (*causal, modern, romantic, natural, classic,* and *elegant*); and (iv) enables a predominant adjective to be assigned to a colour scheme.

The resulting 202 adjectives in Kobayashi's *Colour Image Scale* are very general since a wide range of the aspects are considered. Therefore, if only gastronomy is studied, then a subset of these adjectives that are related with food must be extracted. Hence, 13 adjectives (see Table 1) related to food were selected following the next premises, which are based on the study carried out by[45] where 2000 people from all professions and from all over Germany were consulted on colours-related moods[a]:

- Pink: associated with *delicious* (1) and *sweet-delicate* (2) flavours.
- Red: represents the animals; for children, this colour is associated with *sweetness* (2) because it is the colour of ketchup. It is also the colour related to *hot* (3) and *vigorous* (3) sensations.
- Orange: associated with *exotic* (4), *pleasurable* (6), tasty, and *aromatic* (8) flavours; also in Asian cuisine it is related to a bittersweet taste.
- Yellow: related to acid, to refreshing sensations and to bitterness as it is associated with *citrus* (7) fruits and maturity.
- Green: associated with *healthy* (9), *natural* (10), and *fresh* (11) vegetables, although it is also the colour of immaturity, but combined with brown it is associated with bitter and sour flavors.
- Brown: associated with the strongest flavour (i.e. roasted) and of intense

[a]The number between parentheses indicates the identifier for the relation adjective/colour in Table 1.

aroma. It is also the colour of cooked food and their mainly caloric products *hot* (3) and *vigorous* (3) sensations.

- White: associated with *lightness* (9), white food is attractive, but usually has less nutritional value.
- Blue: according to Spence[29,46] "the colour blue in meat and fish provokes a clear response of *aversion* (13)" .

Furthermore, by taking into account that "the effect of colour depends on previous knowledge",[45] and that in gastronomy "previous knowledge" is usually associated with the traditional food of each culture, the adjective *traditional* (5) has been considered. With this same reasoning, the adjective *Japanese* (12) is also considered, since it is related to the colour of this gastronomy, such as soy sauce, wakame, nori, and kombu. These adjectives are given in Kobayashi's model.

The last adjective included is *Disgusting* (13) (i.e. produce aversion) since it represents the most commonly used negative adjective related to food. According to Curtis[47] disgust matters because it is a strong and visceral emotion that can evoke affective and behavioural responses. As mentioned above, this adjective is also given by Heller[45] when the colour blue is described. But the adjective *disgusting* is not one of Kobayashi's adjectives. For that reason, to obtain a suitable adjective within Kobayashi's model, we took the palettes related to the existing *tasteful* adjective, and computed the corresponding inverse colours in Kobayashi's 2-dimensional colour space. This allows us to define palettes for *Disgusting* within Kobakashi's model as those that are "the opposite of tasteful".

Let us indicate that before developing this research, the adjectives were validated by a chef[b].

The adjectives selected and Kobayashi's palettes are shown in Table 1. This table also shows up to six Kobayashi's colour palettes associated to each adjective (note that some adjectives have less than six colour palettes defined in the model).

To verify the adjectives in the dish's images, the automatic method was applied to associate a Kobayashi's adjective to the colour palette of the appearance of a dish. Then, we developed a survey to validate the labelling obtained automatically by potential tourists. Finally, it presents the regression model developed to quantify the colour harmony in the obtained palette.

The following section develops the procedure of the experiment step by step.

3. Experimentation and Procedure

This section presents the experiment developed and divided into three different steps. First, steps 3.1 shows an automatic method to associate a Kobayashi's adjective to the colour palette of the image of a dish. Then, the second step 3.2 presents a 13-question survey based on Google Forms carried out to collect responses from

[b]The chef has 14 years of experience in restaurants of hospitality industry in Spain, France, Mexico, and Sweden.

Table 1: Adjectives selected and some of the corresponding Kobayashi's colour palettes

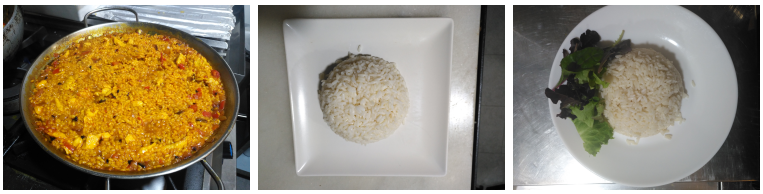
ID	Adjective	Kobayashi's Colour palettes
1	*Delicious*	
2	*Sweet*	
3	*Hot-vigorous*	
4	*Tropical-Exotic*	
5	*Traditional-Ethnic*	
6	*Pleasant*	
7	*Citric*	
8	*Aromatic*	
9	*Healthy-light*	
10	*Natural*	
11	*Fresh*	
12	*Japanese*	
13	*Disgusting*	

potential tourists in order to validate the labelling obtained automatically. Finally, section 3.3 presents the regression model developed to quantify the colour harmony in the obtained palette.

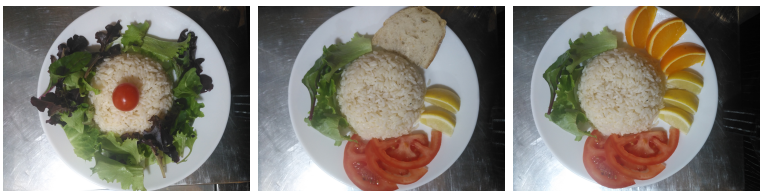
For the choice of images of food dishes, the following recommendation was followed: "The food should not be too elaborate and the colours should be very easy to identify" so that the participants would naturally suggest an adjective. Following this recommendation, our chef cooked more than twenty dishes, several from the Spanish cuisine, from where 9 images[c] were selected for the survey taking into account their colours (see Fig. 1):

- Two dishes in the Spanish cuisine: paella, and spinach with chickpeas (Fig. 1 (a) and (h), respectively).
- Six dishes with white rice placed in the centre in the shape of a semi-spherical mountain. The first picture shows only the rice (Fig. 1 (b)) and in the next white-rice dishes other elements were added: lettuce (Fig. 1 (c)), lettuce and a cherry tomato (Fig. 1 (d)), lettuce, bread, tomato and lemon in slices (Fig. 1 (e)), lettuce, bread, tomato, lemon and orange in slices (Fig. 1 (f)), lettuce, tomato, lemon and orange in slices and some Iberian ham or *jamon serrano* (Fig. 1 (g)).
- A dish of vegetables (Fig. 1 (i)).

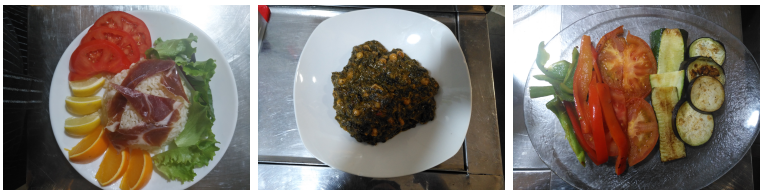
[c]Let us indicate that the pictures of the dishes were taken using the same angle/position of the camera.



(a) Paella (b) Rice (c) Rice lettuce



(d) Rice tomato (e) Rice bread (f) Rice citrus



(g) Rice Iberian ham (h) Spinach with chickpeas (i) Vegetables

Fig. 1: Digital images taken by the chef when cooking some meals.

3.1. *Automatically assigning a Kobayashi's adjective to the image*

This section explains how to automatically assign an adjective/keyword based on Kobayashi's model to the colour palette corresponding to the image of a dish. The process carried out is the following:

- Every picture is segmented, so that only the parts of the image showing food are kept. The segmentation was done automatically by applying the method described in.[48]
- For each image of a dish the most representative Kobayashi's colours of the image are calculated (Kobayashi's model provides the coordinates for 130 colours based on a Munsell-like system). Then, for each combination of three of these colours, a Kobayashi's colour palette is searched. Not all the combinations result in a Kobayashi's colour palette.
- For each Kobayashi's colour palettes obtained before, a keyword/adjective in the Kobayashi's model is assigned. Note that only the Kobayashi's adjectives selected as suitable for the gastronomy case are considered.

For calculating Kobayashi's colours, the Euclidean distance between the RGB colours in the images and the RGB colour representations of Kobayashi's model is used.

3.2. *A survey asking about people's opinion about the dish images*

The survey, which was based on Google Forms, started with three questions about demographic items: gender, age and location of the participants.

In the following ten questions of the survey, participants had to relate the adjectives (in Table 1) with the presented food in Fig. 1. A control question was included to check if the participants were paying attention or not. This control question was: "To check that you are still connected to the survey, please answer never".

With respect to the sample size,[49] let us indicate that if an interval of $(1-\alpha)\%$ confidence of the proportion p is required with an error less or equal to ϵ, the sample size n is calculated as follows:

$$n \geq \frac{p\,(1-p)\,Z^2_{1-\frac{\alpha}{2}}}{\epsilon^2} \tag{1}$$

where Z_u is the u percentile of standard normal distribution.

In our analysis, p takes several values, hence by taking into account that $0 \leq p \leq 1$ is follows: $p(1-p) \leq \frac{1}{4}$ then the sample size must be;

$$n \geq \frac{Z^2_{1-\alpha/2}}{4\,\epsilon^2} \tag{2}$$

and if $\epsilon = 0.1$ and $\alpha = 0.01$ are considered then $n \geq 165.87$ from equation (2). Thus, so that our sample size is representative of an infinite population, our survey must obtain more than 166 responses.

3.3. *Palette Rating*

In order to calculate a rating for all the palettes obtained from the images, a simple regression model was designed that tries to learn user preferences based on the COLOURlovers dataset[d]. This dataset provides a score for 5-palette colours expressed in RGB coordinates, according a voting on a 1-to-5 scale provided by users. However, in this paper 3-palette colours are considered, since experimental studies show that colour triplets strike "good balance for capturing the diversity in colour combination and maintaining manageable complexity for human cognition".[50] Thus, the palette model in COLOURlovers needs to be adapted to the Kobayashi's colour palettes which contains 3 colours in each palette. For that we proceed as follows: (i) first, for each image of a dish, the most representative Kobayashi's colours of the image are calculated and, (ii) then, for each combination of three colours, a

[d]http://www.colorlovers.com/

Kobayashi's colour palette is searched. As a result, we obtain a set of Kobayashi's colour palettes for each 3-colour combination[e].

After the previous palette selection process, several regression methods have been tried, including a SVM with a radial basis function kernel, a random forest, and a LASSO regression. For each model, a cross-validation was used in order to tune the parameters to reduce the mean square error (MSE) metric. Table 2 reports on the mean absolute error (MAE) and the mean absolute percentage error (MAPE) for each method. Note that no significant differences among the different methods have been found; thus, LASSO regression model has been chosen for the palette mapping because it is the simplest method.

Table 2: Performance metrics obtained for SVM, Random forest and LASSO regression methods.

Method	MSE	MAE	MAPE
SVM, RBF kernel	0.7428	0.6612	0.2335
Random Forest	0.6986	0.6845	0.2288
LASSO	0.6975	0.6853	0.2303

4. Analysing and Comparing the Experimental Results

The survey collected 193 responses. 15 responses were discarded due to participants failing to pass the control question. Therefore, finally there were 178 responses to analyse. The demographic distribution of our results is given in Fig. 3.

Table 3: Demographic characteristics of the participants: gender, origin, age.

	Gender	Woman	Men	Total
		90	85	175
	Latin-American	57	33	90
	Spain	33	52	85
Age	< 30	43	47	90
	30-50	30	37	57
	>50	17	11	28

In order to compare the results obtained by the automatic method and the results obtained by the survey, we report the following metrics:

[e]It is important to notice that not all 3-colour combinations represents a valid colour palette in the Kobayashi's model, therefore the combination of colours that are not a corresponding Kobayashi's colour palette (i.e. they are not harmonic) are discarded.

- First, the correlation between all the adjectives obtained by the automatic method and the complete list of adjectives with votes from the survey is measured using a Weighted Kendall's τ (metric WKτ).[51] We use this version instead of the plain Kendall's τ since it fits our case better.
- Then, the accuracy for the first 3 elements of each ranking is calculated too (metric AC@3)
- Moreover, the rating gathered by the regression model developed in section 3.3 is calculated in order to validate how pleasant/harmonic are the Kobayashi's colour palettes obtained for each image. We report the average score of all such palettes (metric *mean palette score*, MPS).

All these results are summarised in Tables 4 and 5.

Table 4 presents the results obtained from the participants in the the survey: each cell shows the number of votes accumulated by each image (in the rows denoted by a-i) related to each adjective (in the columns denoted by 1-13, in the same order shown in Table 1).

Table 4: Number of times that a participant voted for each adjective for each image in the survey: in horizontal, the pictures are referenced by letters (a–i) and, in vertical, the adjective identifiers in Table 1 are provided (1–13).

	1	2	3	4	5	6	7	8	9	10	11	12	13
a	44	0	26	9	**70**	10	2	7	0	2	0	2	6
b	7	2	2	0	37	6	0	0	**63**	9	18	28	6
c	1	1	2	5	17	14	1	5	**77**	15	31	6	2
d	8	0	2	8	6	20	0	6	**68**	24	29	5	2
e	10	1	1	9	15	18	15	3	**66**	10	26	1	3
f	4	4	1	24	7	12	33	4	**56**	6	22	0	5
g	19	2	4	**28**	12	24	10	7	18	22	13	0	19
h	6	3	20	9	49	2	2	8	2	9	1	2	**65**
i	8	0	4	9	9	6	0	3	**93**	26	12	4	4

Table 5 shows the results obtained by our automatic methods and compare the results to the adjectives provided by participants in the survey. The first column shows the image label; the second column presents the results of the automatic labelling, showing the three adjectives with the highest score; the third column presents the three most selected adjectives by the participants of the survey (extracted from Table 4); the fourth column presents the Weighted Kendall's τ between the rank of all the adjectives detected by the Kobayashi's method and the rank of the adjectives voted by the participants in the survey; the fifth column presents the Accuracy@3; and finally the average rating of Kobayashi's colour palettes obtained

for each image is shown.

Table 5: Kobayashi's culinary adjectives associated to each image from Fig. 1, first using the automatic labelling and then gathering the participants' answers in the survey.

Image	Automatic Adjectives	Adjectives in survey	WKτ	AC@3	MPS
a	Aromatic, Traditional-Ethnic, Natural-Wild	Traditional-Ethnic, Delicious, Hot-Vigorous	0.476	0.333	2.792
b	Healthy-Light, Fresh, Pleasant	Healthy-Light, Traditional-Ethnic, Japanese	0.505	0.333	2.843
c	Healthy-Light, Fresh, Pleasant	Healthy-Light, Fresh, Traditional-Ethnic	0.608	0.667	2.843
d	Healthy-Light, Fresh, Pleasant	Healthy-Light, Fresh, Natural-Wild	0.320	0.667	2.843
e	Healthy-Light, Fresh, Pleasant	Healthy-Light, Fresh, Pleasant	0.530	1.000	2.843
f	Healthy-Light, Fresh, Pleasant	Healthy-Light, Citric, Tropical-Exotic	0.548	0.333	2.843
g	Healthy-Light, Fresh, Pleasant	Tropical-Exotic, Pleasant, Natural-Wild	0.277	0.333	2.843
h	Healthy-Light, Pleasant, Traditional-Ethnic	Disgust-Aversion, Traditional-Ethnic, Hot-Vigorous	-0.287	0.333	2.849
i	Healthy-Light, Pleasant, Aromatic	Healthy-Light, Natural-Wild, Fresh	0.092	0.333	2.835

The weighted Kendall's τ correlation (WKτ) is higher than 0.3 in most of the cases which represents a good correlation. Note that in the case of image (h) a negative value of WKτ is obtained which means that the same adjectives are correlated but in inverse order. The AC@3, which calculates the accuracy of the 3 most voted adjectives in both methods, shows also acceptable performance. The Mean Palette Score (MPS) shows also values around 3 in the scale 1–5, which validate that the colour palettes are pleasant enough for potential viewers.

It is important to notice that the results obtained by the automatic method are obtained considering only the colours in the image of the dish, and participants of the survey are influenced by cultural connotations associated with the food shown and not only by the colours in the image. As an example of this difference, Table 6

shows that 48 out of the 90 Latin-American participants answered with the adjective *Disgust-Aversion* when showing them Fig. 1(h) "Spinach with chickpeas", that is, the sample proportion is 0.53. This can be motivated by the fact that this dish is not previously known by the Latin-American participants. But, the final results considering all the participants shows that "Disgusting" is between the 3 most voted moods, mainly because the rest of participants recognised the dark coloured vegatables in the dish.

Table 6: Answers for the dish in Fig. 1(h) "Spinach with chickpeas".

	1	2	3	4	5	6	7	8	9	10	11	12	13
Latin American	2	3	6	8	7	0	2	6	0	5	1	2	**48**
Others	4	0	14	1	42	2	0	2	2	4	0	0	17

5. Conclusion

Our main goal was to reveal how the colour of food elicits opinions that may end in positive or negative decisions in the final choice of a restaurant or destination. For this purpose, we have developed an automatic method for associating an emotional or mood adjective to pictures of meals based on Kobayashi's *Colour Image Scale* method. With this automatic method, we have shown that different colours palettes in an image of a meal can have different emotional impact in people. Moreover, the intensity of the emotion associated to each meal can also be measured by the rating method, developed by using a regression model trained on the ColorLovers dataset. Finally, in order to validate the automatically generated emotions, we designed a survey, which 178 participants responded. The analysis of the results demonstrated that the automatic method adequately labelled the images of meals in a way which is consistent with human-expressed preferences.

These results open new possibilities for applications in the field of tourism destination marketing, which require knowledge of gastronomic products (local food, food culture) for the effective promotion destinations.[8,16,17] A current search of #food on Instagram retrieves 496 million pictures; therefore, selecting the best photo to advertise our destination is complicated, especially if it is necessary to the take in to account specific characteristics of target consumer, such as nationality or age, etc. In this context, our results provide a step towards providing tools to marketing professionals that help improve the advertising of gastronomic products and create an attractive gastronomic image of a restaurant or destination since, as we have shown, it is essential to take into account the colour of images and the moods elicited by them.

6. Future Work

In the literature there are few research papers related to the topic of food colour and tourism, therefore it is a novel subarea for research on tourism and food technology.

This study provides empirical evidence of the usefulness of mood adjectives extracted through colours for categorizing culinary images from Spanish and Latin-American people. However, this study does not ensure that the results can be translated to other countries' population. As future work, we intend to extend the survey to gather responses by people from other cultures in order to extend the results.

Due to the restrictions caused by the latest pandemic, the survey to validate the culinary adjectives was conducted online. In the future, we intend to carry out a study in person, since it may provide a deeper insight into how colours affect the perception of food. Apart from sight, food is perceived by other senses and we also categorize it through them: we can smell food (i.e. minty, floral, lemony), we can touch food (i.e. sticky, smooth), and we also can hear food (i.e. crunchy, crispy). Only in-person experiment will allow us to access this richer quantity of culinary adjectives, in order to study thee relation of food colour with the cognitive perception of the showed meals. Further studies are intended in this direction.

Regarding further computational developments, there are several techniques we are exploring in order to deal with more complex images (e.g. with heavy shadows or complex patterns in plates, which may affect the segmentation). Current advances in deep learning provide a rich set of tools that can be applied to this problem.

Our future goal is to develop a complete recommender system tool that can be used for marketing issues considering restaurants and promoters of gastronomic tourism that advertise on social networks (e.g., Instagram, Facebook), so that depending on the feelings they want to convey about their business or destinations, they can present images that contain certain colour palettes in their meals, in order to make their product more attractive for potential tourist or consumers.

Acknowledgments

This work has been funded by the Spanish Ministry of Science, Innovation and Universities through the project *Prueba de Concepto para la Plataforma de Análisis Social Dinámico en el Contexto del Turismo Sostenible* (PDC2021-121097-I00), and through the EDITH Research Project (PGC2018-102145-B-C21). The funding by the Spanish Ministry of Economy and Commerce with project contract TIN2016-88835-RET and the funding provided by Universitat Jaume I under project UJI-B2020-15 are also acknowledged.

Z. Falomir acknowledges the Ramon y Cajal fellowship (RYC2019-027177-I / AEI / 10.13039/501100011033) and V. Casales-Garcia acknowledges the FPU 17/00014 both awarded by the Spanish Ministry of Science, Innovation and Universities.

References

1. UNWTO, "Global report on food tourism", Technical report, United Nations World Tourism Organization, Madrid, Spain, 2012.
2. M. I. Profiles, "Global Travel & Tourism", Technical Report December, Marketline Industry Profiles, 2018.
3. K. Chon, "The role of destination image in tourism: A review and discussion", *The Tourist Review* **45** (1990) 2–9.
4. C. M. Echtner and J. B. Ritchie, "The measurement of destination image: An empirical assessment", *Journal of Travel Research* **31** (1993) 3–13.
5. C. M. Echtner and J. B. Ritchie, "The meaning and measurement of destination image", *Journal of tourism studies* **14** (2003) 37–48.
6. M. G. Gallarza, I. G. Saura and H. C. García, "Destination image: Towards a conceptual framework", *Annals of Tourism Research* **29** (2002) 56 – 78.
7. S. Pike, "The use of repertory grid analysis to elicit salient short-break holiday destination attributes in new zealand", *Journal of Travel Research* **41** (2003) 315–319.
8. C. C.Richard and M. H. Athena,"Understanding gastronomic image from tourists perspective: A repertory grid approach",*Tourism Management* **68** (2018) 89–100.
9. S. Baloglu and K. W. McCleary, "A model of destination image formation", *Annals of Tourism Research* **26** (1999) 868 – 897.
10. A. BeerliandJ. D. Martín,"Factors influencing destination image", *Annals of Tourism Research* **31** (2004) 657 – 681.
11. Y. Ekinci and S. Hosany, "Destination personality: An application of brand personality to tourism destinations", *Journal of Travel Research* **45** (2006) 127–139.
12. A. Duarte Alonso, "Olives, hospitality and tourism: a Western Australian perspective", *British Food Journal* **112** (2010) 55–68.
13. S. Quan and N. Wang, "Towards a structural model of the tourist experience: An illustration from food experiences in tourism", *Tourism Management* **25** (2004) 297–305.
14. S. Smith and C. Costello, "Segmenting Visitors to a Culinary Event: Motivations, Travel Behavior, and Expenditures", *Journal of Hospitality Marketing & Management* **18** (2009) 44–67.
15. P. Björk and H. Kauppinen-Räisänen, "Culinary-gastronomic tourism–a search for local food experiences", *Nutrition & Food Science* .
16. J.-S. Horng and C.-T. S. Tsai], "Government websites for promoting east asian culinary tourism: A cross-national analysis", *Tourism Management* **31** (2010) 74 – 85.
17. B. Okumus, F. Okumus and B. McKercher, "Incorporating local and international cuisines in the marketing of tourism destinations: the cases of Hong Kong and Turkey.", *Tourism Management* **28** (2007) 253–261.
18. A. Lepp, H. Gibson and C. Lane, "Image and perceived risk: A study of uganda and its official tourism website", *Tourism Management* **32** (2011) 675–684.
19. C. Spence and B. Piqueras-Fiszman, *Food Color and Its Impact on Taste/Flavor Perception* (Elsevier Ltd, 2016).
20. M. Abdullah, L. Guan, K. Lim and A. Karim, "The applications of computer vision system and tomographic radar imaging for assessing physical properties of food", *Journal of Food Engineering* **61** (2004) 125 – 135, applications of computer vision in the food industry.
21. H. Afshari-Jouybari and A. Farahnaky, "Evaluation of photoshop software potential for food colorimetry", *Journal of Food Engineering* **106** (2011) 170 – 175.
22. L. Fernández, C. Castillero and J. Aguilera, "An application of image analysis to dehydration of apple discs", *Journal of Food Engineering* **67** (2005) 185 – 193, iV

Iberoamerican Congress of Food Engineering (CIBIA IV).
23. F. Mendoza, P. Dejmek and J. M. Aguilera, "Calibrated color measurements of agricultural foods using image analysis", *Postharvest Biology and Technology* **41** (2006) 285 – 295.
24. F. Birren, "Color & human appetite", *Food Technology* **17** (1963) 553–555.
25. J. Roque, C. Guastavino, J. Lafraire and P. Fernandez, "Plating influences diner perception of culinary creativity", *International Journal of Gastronomy and Food Science* **11** (2018) 55 – 62.
26. M. Lightner and S. Rand, "The enhancement of natural colors to provoke seasonality", *International Journal of Gastronomy and Food Science* **2** (2014) 55 – 59.
27. K. Shimoda and S. Hidaka, "Investigation of the effects of color on judgments of sweetness using a taste adaptation method", *Multisensory Research* **27** (2014) 189–205.
28. G. Morrot, F. Brochet and D. Dubourdieu, "The Color of Odors", *Brain and Language* **79** (2001) 309–320.
29. C. Spence, *Gastrophysics : The New Science of Eating* (Viking, [New York], 2017).
30. B. Piqueras-fiszman, J. Alcaide, E. Roura and C. Spence, "Is it the plate or is it the food ? Assessing the influence of the color (black or white) and shape of the plate on the perception of the food placed on it", *Food Quality and Preference* **24** (2012) 205–208.
31. Z. Falomir, V. Costa and L. G. Abril, "Obtaining discriminative colour names according to the context: Using a fuzzy colour model and probabilistic reference grounding", *Int. J. Uncertain. Fuzziness Knowl. Based Syst.* **27** (2019) 107–142.
32. C. Spence, "Background colour & its impact on food perception & behaviour", *Food Quality and Preference* **68** (2018) 156 – 166.
33. L. Sun-Man, L. Kyoung-Taek, L. Seong-Hyun and S. Jang-Kun, "Origin of human colour preference for food", *Journal of Food Engineering* **119** (2013) 508–515.
34. K. B. Schloss, E. D. Strauss and S. E. Palmer, "Object color preferences", *Color Research & Application* **38** (2012) 393–411.
35. M. Paakki, I. Aaltojärvi, M. Sandell and A. Hopia, "The importance of the visual aesthetics of colours in food at a workday lunch", *International Journal of Gastronomy and Food Science* **16** (2019) 100131.
36. H. N. Schifferstein, T. Wehrle and C.-C. Carbon, "Consumer expectations for vegetables with typical and atypical colors: The case of carrots", *Food Quality and Preference* **72** (2019) 98–108.
37. S. Kobayashi, *Color image scale* (Kosdansha International, 1991).
38. S. Horiguchi and K. Iwamatsu, "From munsell color system to a new color psychology system", *Color Research and Application* **43** (2018) 827–839.
39. G. Moretti, P. Lyons and S. Marsland, "Computational production of colour harmony. part 1: A prototype colour harmonization tool", *Color Research & Application* **38** (2013) 203–217.
40. D. B. Judd, "Color in business, science, and industry", *Journal of the American Pharmaceutical Association (Scientific ed.)* **42** (1953) 757.
41. K. E. Burchett, "Color harmony", *Color Research & Application* **27** (2002) 28–31.
42. D. Cohen-Or, O. Sorkine, R. Gal, T. Leyvand and Y.-Q. Xu, "Color harmonization", *ACM Transactions on Graphics (TOG) - Proceedings of ACM SIGGRAPH 2006* **25** (2006) 624–630.
43. L. Museros, I. Sanz, Z. Falomir and L. Gonzalez-Abril, "Creating, Interpreting and Rating Harmonic Colour Palettes Using a Cognitively Inspired Model", *Cognitive Computation* **12** (2020) 442–459.

44. S. Kobayashi, "The aim and method of the color image scale", *Color Research & Application* **6** (1981) 93–107.
45. E. Heller, *Wie Farben auf Gefühl und Verstand wirken: Farbpsychologie, Farbsymbolik, Lieblingsfarben, Farbgestaltung* (Droemer, 2000).
46. C. Spence, "What is so unappealing about blue food and drink?", *International Journal of Gastronomy and Food Science* **14** (2018) 1 – 8.
47. V. Curtis, "Why disgust matters", *Philosophical transactions of the Royal Society of London. Series B, Biological sciences* **366** (2011) 3478–3490.
48. D. Park, J. Lee, J. Lee and K. Lee, "Deep learning based food instance segmentation using synthetic data", in *2021 18th International Conference on Ubiquitous Robots (UR)* (2021), pp. 499–505.
49. W. G. Cochran, *Sampling Techniques, 3rd Edition.* (John Wiley & Sons, 1977).
50. L. Yao, P. Suryanarayan, M. Qiao, J. Wang and J. Li, "Oscar: On-site composition and aesthetics feedback through exemplars for photographers", *International Journal of Computer Vision* **96** (2012) 353–383.
51. S. Vigna, "A weighted correlation index for rankings with ties", in *Proceedings of the 24th International Conference on World Wide Web* (International World Wide Web Conferences Steering Committee, Republic and Canton of Geneva, CHE, 2015), WWW'15, p.1166–1176.
52. T. D. Andersson, L. Mossberg and A. Therkelsen, "Food and tourism synergies: perspectives on consumption, production and destination development", *Scandinavian Journal of Hospitality and Tourism* **17** (2017) 1–8.
53. J. Prada-Trigo, "Tourism, territory and cuisine: food consideration and perceptions regarding origin and social changes: the case of guinea pig", *Journal of Tourism and Cultural Change* **16** (2018) 400–415.
54. M. A. Mubeen, "Are you selling the right colour? a cross?cultural review of colour as a marketing cue", *Journal of Marketing Communications* **12** (2006) 15–30.