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Original Article

# Estimation of the nutritional balance of food dishes by color analysis of photographs - using salad as a model dish

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## Summary

The possibility of the estimation of nutritional balance using color analysis of photographs of food dishes was investigated in the case of salad. A total of 78 photographs of different salad varieties obtained from a recipe book and recipe website were analyzed. The ingredients of each salad were painted with 10 different colors and the area % of each color was calculated using the Feelimage Analyzer (VIVA Computer Ltd.). The weight average food composition was determined for each color using recipes indicating trace nutrients and dietary fiber. The amounts of ingredients estimated by color analyses were corrected using correlation equations obtained from the correlation analyses between the amount of nutrients estimated from the area % of the color and the amounts calculated per 100 g of salad from the recipe. The estimated nutrient content obtained using the weight average food composition for each color was then compared with those calculated per 100 g of salad based on the recipe. Of the 78 varieties of salad analyzed, in more than 50 % of cases the contents of potassium, dietary fiber, vitamin $B_1$ and phosphorus could be estimated to within ±30 % of those calculated from recipe. In order to validate this method, an additional three varieties of salad were analyzed. While the possibility of the evaluation of nutritional balance using color analysis of salad photographs was suggested by the results of this study, an increase in accuracy to estimate the amounts of ingredients and the weight average food composition for each color will be required.

## Introduction

At present, there are a number of dietary lifestyle-related issues in Japan. In particular, the increase in lifestyle-based diseases, including cancer and cardiovascular disease, is an important social issue. A National Health and Nutrition Examination Survey conducted in 2011 reported that 30.3 % of men and 21.5 % of women over the age of 20 were obese, and 15.7 % of men and 7.6 % of women had pre-diabetes, about 1.3 times higher than reported in 2006.

In response to these issues, the *Shokuiku Basic Act* was passed by the Cabinet Office in 2005 and the *Shokuiku Promotion Basic Plan* was implemented in 2006 in order to promote *Shokuiku*, or food education, for all Japanese in order to promote healthy dietary habits. That is to say the cultivation of the ability to manage one's healthy dietary life is expected. However, it may be difficult for individuals who lack adequate knowledge about nutrition and food to make appropriate food choices. In addition, opportunities to learn how to select and prepare food in order to maintain and/or promote one's health are decreasing due to changes in lifestyle and the increasing prevalence of ready-made meals and dining-out.

On the other hand, due to the progress of IT and the widespread use of digital cameras, mobile phones and smart phones, many studies have been reported describing the estimation of the ingested nutrients of a meal from a photograph[1-5)]. Although the photographic diet record method was easy for diners, the determination automatically the menu and the estimation of the amounts of ingredients from a one-dimensional photograph were difficult and inaccurate.

For proper dietary management, not only are the amounts of nutrients ingested important, but also the nutritional balance. Therefore, in the present study the possibility of evaluating nutritional balance using color analysis of photographs of food dishes was demonstrated using salad as a model.

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## Materials and Methods

### 1. Materials

A total of 78 photographs of different varieties of salads obtained from a recipe book[6] and recipe website[7], where the amount of each ingredient was indicated, were analyzed. In this study, salads which consisted primarily of seafood, such as conger eel, salmon roe, crab, shrimp, and scallop, and those containing a large amount of sauce were excluded from the analyses.

### 2. Color analysis of salad photographs

Using Adobe Photoshop 7.0, the ingredients in each salad photograph were painted with one of 10 colors, *i.e.*, black, white, green, yellow-green, yellow, orange, red, brown, pink or purple, and the serving dish and background were painted blue in order to exclude it from color analysis. The area % of each color in the salad was calculated by using the Feelimage Analyzer (VIVA Computer Ltd.).

### 3. Revision the estimated amounts of ingredients

Correlation analyses between the amounts estimated from the area % of color and those calculated from the recipe per 100 g of salad were performed for all 10 colors. Using the correlation equation obtained for each color, the estimated amounts were revised to approximate the amounts calculated for all 78 varieties of salads.

### 4. Nutritional analysis

Based on the amounts of ingredients per 100 g of each of the 78 varieties of salads shown in the recipes, a weight average food composition table was prepared for all 10 colors using Excel *eiyou-kun* Ver.6 indicating the amount of potassium, calcium, magnesium, phosphorus, iron, retinol equivalent, vitamin $B_1$, vitamin $B_2$, folic acid, vitamin C and dietary fiber.

### 5. Revision of the estimated amount of nutrients

The estimated nutritional content was obtained using the revised % area and the weight average food composition, and was calculated per 100 g of salad using the recipes for each of the 78 salads. A correlation analysis was performed for the amounts of 11 different nutrients; potassium, calcium, magnesium, phosphorus, iron, retinol equivalent, vitamin $B_1$, vitamin $B_2$, folic acid, vitamin C and dietary fiber, and the resulting correlation equations were used to revise the estimated nutrient contents to more closely reflect the calculated amounts. This method was then used to compare the estimated and calculated amounts of nutrients in the salads.

### 6. Validation of the use of color analysis of salad photographs to estimate nutritional balance

In order to verify the possible use of color analyses to estimate the nutritional balance from salad photographs, three additional varieties of salads (pumpkin salad, greens and chicken salad , Bagna Cauda salad) as shown in Fig. 1 were analyzed using the correlation formulae and weight average food composition. The estimated amounts of nutrients were then compared with those obtained per 100 g of salads using the recipes and Excel *eiyou-kun* Ver.6.


**Fig. 1** Three additional varieties of salad used for validation
a. pumpkin salad
b. greens and chicken salad
c. bagna cauda salad

### 7. Statistical analysis

Correlation analyses were performed by using Microsoft Excel 2010.

## Results and Discussion

### 1. Color analyses

The area % of each of 10 different colors in photographs of 78 varieties of salads is shown in Fig. 2, and the weight % of the ingredients represented by each color is shown in Table 1. The area % of white was the largest (30.2 %) followed by yellow-green (22.1 %) and green (21.5 %). The total area % of white, yellow-green, and green colors in 78 varieties of salad accounted for more 70 % of the area, due

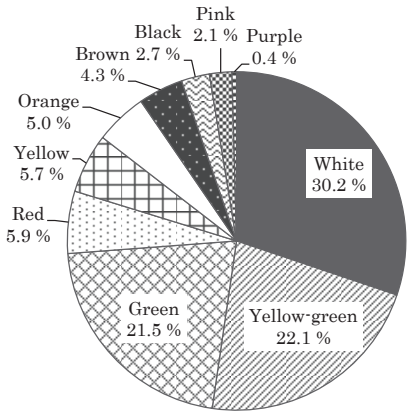


**Fig. 2** The area % of each color in 78 salad photographs

■White ▨Yellow-green ▩Green □Red ▫Yellow
□Orange ■Brown ▨Black ▩Pink ▤Purple

**Table 1** Weight % of the ingredients in each color category

| Color | Weight % of the ingredient in each color |
|---|---|
| White | potato (17.5 %), onion (13.4 %), japanese radish (8.7 %), tofu (6.4 %), cauliflower (6.0 %), bean sprout (5.9 %), tuna (4.6 %), apple (3.2 %), celery (3.1 %), soybean (2.2 %), cuttlefish (2.0 %), yam (2.0 %), macaroni (2.0 %), turnip (1.9 %), egg white (1.8 %), lotus root (1.6 %), zucchini (1.5 %), sweet potato (1.4 %), eggplant (1.3 %), udo (1.2 %), radish (1.2 %), agar (1.1 %), shiitake mushroom (1.1 %), minced chicken (1.1 %), fried tofu (1.1 %), enoki mushroom (1.0 %), hiratake mushroom (0.7 %), boiled scallop (0.5 %), boiled crab (0.5 %), cheese spread (0.4 %), chicory (0.4 %), asparagus (0.4 %), mushroom (*shimeji*) (0.4 %), cod roe (*mentaiko*) (0.4 %), kidney beans (0.3 %), peanut (0.3 %), steamed fish paste (0.2 %), white radish sprouts (0.2 %), pickled cucumber (0.1 %), process cheese (0.1 %), sesame (0.1 %), roasted sesame (0.1 %) |
| Yellow-green | lettuce (30.4 %), cucumber (24.5 %), cabbage (21.6 %), green soybean (6.7 %), lettuce (*saladana*) (6.2 %), celery (3.4 %), broccoli (2.1 %), red leaf lettuce (1.5 %), endive (1.3 %), asparagus (1.2 %), string been (*sayaingen*) (0.7 %), bitter melon (0.3 %) |
| Green | string been (*sayaingen*) (24.9 %), spinach (14.7 %), corn marigold (8.6 %), string been (*sayaendou*) (6.8 %), cucumber (6.5 %), lettuce (*saladana*) (5.5 %), green pepper (4.4 %), broccoli (3.9 %), seaweed (*kukiwakame*) (3.7 %), bitter melon (3.6 %), watercress (2.4 %), rape blossoms (2.4 %), potherb mustard (2.4 %), dried wakame (1.9 %), asparagus (1.6 %), parsley (1.5 %), endive (1.4 %), white radish sprouts (0.9 %), zucchini (0.8 %), raw wakame (0.7 %), wakegi (0.6 %), pumpkin (0.6 %) |
| Red | tomato (64.4 %), red pepper (16.0 %), mini-tomato (14.4 %), apple (1.6 %), bacon (1.2 %), sweet potato (1.0 %), radish (1.0 %), crab (0.3 %) |
| Yellow | grapefruit (24.3 %), sweet potato (19.5 %), sweet corn (18.4 %), yellow pepper (14.4 %), egg yellow (7.1 %), bean sprout (6.8 %), process cheese (4.1 %), young corn (2.9 %), pineapple (2.6 %) |
| Orange | carrot (63.1 %), pumpkin (32.0 %), tomato (4.9 %) |
| Brown | sausage (17.8 %), common mushroom (14.9 %), mushroom (*shimeji*) (11.0 %), shiitake mushroom (9.1 %), tuna (8.0 %), enoki mushroom (6.8 %), mushroom (*maitake*) (6.8 %), dried fry (*shirasu*) (5.9 %), kidney bean (5.0 %), raisin (4.2 %), bacon (3.9 %), red leaf lettuce (2.1 %), black olive (2.0 %), umeboshi (1.1 %), pleurotus mushroom (1.1 %), dried bonito (0.5 %) |
| Black | dried wakame (28.9 %), salted kombu (18.9 %), hijiki (18.6 %), eggplant (12.1 %), black olive (11.6 %), raw wakame (9.9 %) |
| Pink | ham (53.4 %), bacon (14.4 %), sausage (9.1 %), salami (8.8 %), red pea (8.7 %), japanese ginger (5.5 %) |
| Purple | seaweed (*tosakanori*) (100.0 %) |

to the fact that the ingredients classified into these colors (potato, onion, lettuce, cucumber) were used more frequently regardless of the variety of salad. On the other hand, the small area % of brown and pink colors represented animal foods such as sausage, ham and bacon. The purple color consisted of only seaweed (*tosakanori*) in the 78 varieties of salads examined.

## 2. Correlation of the estimated amounts of ingredients with those calculated from the recipes

The correlation coefficients obtained from the correlation analyses between the estimated amounts, shown as the area %, and the calculated amounts of ingredients per 100 g of salad using the recipes, is shown in Table 2 for each of the 10 color categories. A representative correlation analysis for the color green is shown in Fig. 3. The estimated amounts of ingredients classified as the color brown showed the highest correlation coefficient (r = 0.94) among the 10 colors. In the case of the other 8 colors, with the exception of purple which consisted of only one ingredient, the correlation coefficients were greater than 0.70. However, the estimated ingredients classified into the white and red colors were found to be less than when calculated from recipe.

In order to more closely approximate the estimated amounts shown as area % to the amounts calculated from recipes, the area % of each color was corrected using a correlation equation as shown in Table 2.

**Table 2** Correlation analyses between the estimated and calculated amounts of ingredients in each color category

| | Correlation coefficient | Correlation equation | Revision equation |
|---|---|---|---|
| Brown | 0.94 | y = 0.8939x | × 0.8939 |
| Red | 0.89 | y = 1.2649x | × 1.2649 |
| Yellow | 0.88 | y = 0.8147x | × 0.8147 |
| White | 0.87 | y = 1.2636x | × 1.2636 |
| Yellow-green | 0.82 | y = 0.8073x | × 0.8073 |
| Pink | 0.82 | y = 0.8172x | × 0.8172 |
| Green | 0.73 | y = 0.7059x | × 0.7059 |
| Black | 0.73 | y = 0.2738x | × 0.2738 |
| Orange | 0.72 | y = 0.7101x | × 0.7101 |
| Purple | 1.00 | y = 1.0956x | × 1.0956 |

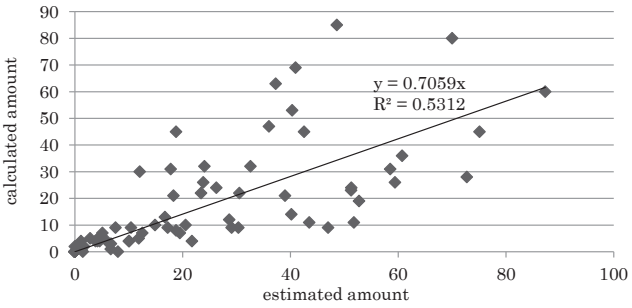


**Fig. 3** Representative correlation analysis in the case of green color category

### 3. Nutritional analyses

In order to carry out the nutrition analyses, the weight average food composition for each of the 10 colors was obtained using the weight % of ingredients shown in the recipes as shown in Table 3.

According to the weight average food composition of each color category, the ingredients classified into the black color category were found to contain more potassium, calcium, magnesium, iron and dietary fiber, while those classified into the green color category contained more folic acid, those classified into the orange color category had higher retinol equivalent, and those classified into the pink color category contained more phosphorus and vitamin $B_1$.

### 4. Correlation analyses between the estimated and calculated nutrient contents

Correlation analyses between the estimated nutrient contents obtained by using the revised area % and the weight average food composition table, and the calculated nutrient contents per 100 g of salads were performed. The correlation coefficients for the 11 different nutrients are shown in Table 4, and a representative correlation analysis in the case of vitamin $B_2$ is shown in Fig. 4. The correlation coefficient of iron was the highest (r = 0.71) among the nutrients analyzed, followed by vitamin $B_2$ (r = 0.67), dietary fiber (r = 0.63) and retinol equivalent (r = 0.61). However, that of folic acid was the lowest (r = 0.28). Green and yellow-green vegetables are generally thought to be the main sources of folic acid. Although green and yellow-green vegetables are often the main ingredients in salad, their nutrient estimation was difficult, since they were in some cases underestimated by being covered with other colorful vegetables used as toppings, but also overestimated due to the large surface area when served in shallow plate in spite of their light weight per volume.

Fig. 5 shows the percentage of 11 different nutrients which were estimated to within ±30 % and/or ±50 % of the calculated values in the 78 varieties of salads. In the case of potassium, dietary fiber, vitamin $B_1$ and phosphorus, they could be estimated to within ±30 % of the calcu-

**Table 4** Correlation analyses between the estimated and calculated nutrients

| | Correlation coefficient | Correlation equation | Revision equation |
|---|---|---|---|
| Iron | 0.71 | y = 1.1109x | × 1.1109 |
| Vitamin $B_2$ | 0.67 | y = 1.0344x | × 1.0344 |
| Dietary fiber | 0.63 | y = 1.0163x | × 1.0163 |
| Retinol equivalent | 0.61 | y = 0.8550x | × 0.8550 |
| Magnesium | 0.51 | y = 1.0206x | × 1.0206 |
| Calcium | 0.47 | y = 1.0246x | × 1.0246 |
| Vitamin $B_1$ | 0.47 | y = 0.9801x | × 0.9801 |
| Vitamin C | 0.39 | y = 1.0177x | × 1.0177 |
| Phosphorus | 0.39 | y = 0.9743x | × 0.9743 |
| Potassium | 0.37 | y = 1.0019x | × 1.0019 |
| Folic acid | 0.28 | y = 0.9348x | × 0.9348 |

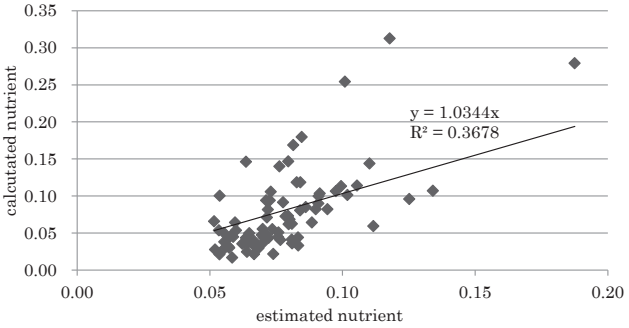


**Fig. 4** Representative correlation analysis in the case of vitamin $B_2$

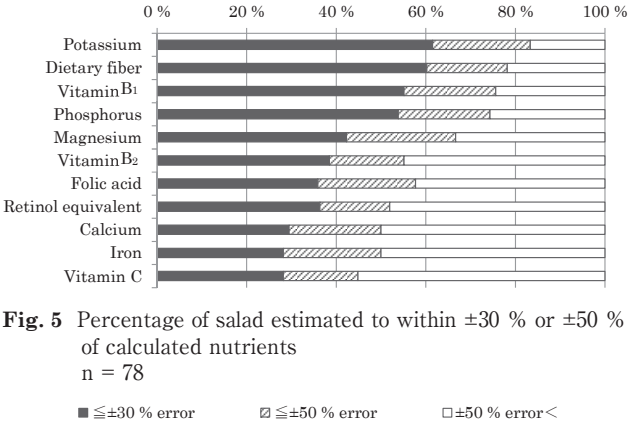


**Fig. 5** Percentage of salad estimated to within ±30 % or ±50 % of calculated nutrients
n = 78

**Table 3** The weight average food composition table for 10 color categories

| | Potassium (mg) | Calcium (mg) | Magnesium (mg) | Phosphorus (mg) | Iron (mg) | Retinol equivalent (μg) | Vitamin $B_1$ (mg) | Vitamin $B_2$ (mg) | Folic acid (μg) | Vitamin C (mg) | Dietary fiber (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Black | 1332 | 370 | 203 | 72 | 11.3 | 94 | 0.11 | 0.30 | 39 | 3 | 13.1 |
| White | 253 | 32 | 20 | 63 | 0.5 | 3 | 0.06 | 0.06 | 27 | 17 | 1.6 |
| Yellow-green | 249 | 34 | 16 | 41 | 0.6 | 33 | 0.06 | 0.05 | 78 | 19 | 1.7 |
| Green | 358 | 61 | 33 | 47 | 1.2 | 150 | 0.08 | 0.13 | 111 | 35 | 2.8 |
| Yellow | 202 | 51 | 14 | 98 | 0.7 | 46 | 0.07 | 0.09 | 39 | 37 | 1.6 |
| Orange | 325 | 22 | 14 | 30 | 0.3 | 537 | 0.05 | 0.05 | 29 | 17 | 2.7 |
| Red | 226 | 9 | 11 | 29 | 0.3 | 55 | 0.06 | 0.05 | 32 | 43 | 1.2 |
| Brown | 319 | 43 | 23 | 169 | 0.8 | 18 | 0.17 | 0.21 | 30 | 5 | 2.5 |
| Purple | 37 | 70 | 31 | 11 | 1.2 | 1 | 0.00 | 0.04 | 0 | 0 | 4.0 |
| Pink | 242 | 12 | 21 | 258 | 0.8 | 2 | 0.46 | 0.12 | 3 | 35 | 0.8 |

lated value in more than 50 % of the 78 salads. These results would suggest that color analysis may be a possible method to estimate the amount of nutrients in salad.

### 5. The verification of the estimation of nutritional balance using color analysis

In order to further validate the use of color analysis to estimate nutritional balance, an additional three varieties of salad (Fig. 1) were analyzed using the correlation formula and the weight average food composition obtained in this study. The estimated nutritional balances per 100 g for the three varieties of salads were compared to those calculated from their recipes, and are shown in Fig. 6–8. In the case of pumpkin salad, 8 of the 11 nutrients were estimated to within ±30 % of the calculated value. In the case of greens and chicken salad, calcium, magnesium and vitamin $B_1$ were estimated to within ±30 % of the calculated value. In the case of bagna cauda salad, many of the nutrients were overestimated, primarily because it was served in a large and shallow plate.

Salad is prepared by a simple procedure and is rich in colors. Thus, salad photographs were analyzed in order to investigate the possibility of estimation of the nutritional balance by applying color analysis. The results of the present study using salad photographs suggested that color analysis may potentially be a useful technique to estimate the nutritional balance of foods; however a number of issues would still need to be addressed. In order to classify the ingredients into the 10 color categories as used in this study, the ingredients in photographs must be prepainted using computer software (Adobe Photoshop). This step would need to be automatically performed when the essential conditions to classify the color of ingredients become clear through further investigation. And more salad photographs will need to be analyzed in order to increase the accuracy in estmating the amounts of ingredients and the weight average food composition. In particular, the weight average food composition of the color purple in this study consisted of only seaweed (*tosakanori*), and salads which consisted primarily of meat or seafood were excluded in this study. In addition, the energy intake was not analyzed. Finally, the estimation of the amounts of salad dressing, some of which are not photographed, is impossible. In order to solve this problem, the average amounts of energy obtained from dressing must be added evenly.

The correlation coefficient of the famous dietary management system called “FoodLog” invented by Miyazaki etc. [1] was reported to be 0.32, which could carry out the analysis of various dishes. The reason why the correlation

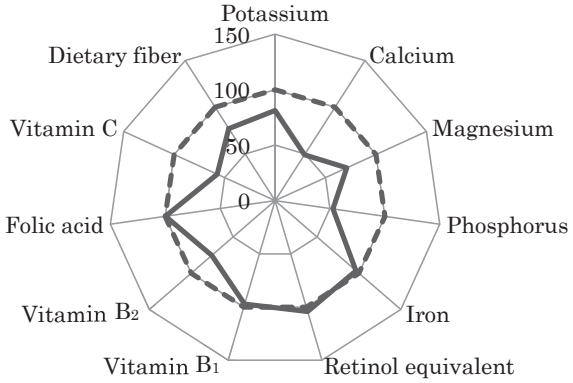


**Fig. 6** The comparative amounts of nutrients estimated for those calculated per 100 g of the pumpkin salad

calculated amount of nutrient — estimated amount of nutrient

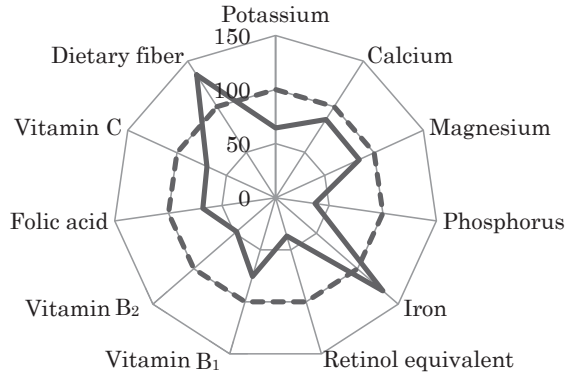


**Fig. 7** The comparative amounts of nutrients estimated for those calculated per 100 g of the greens and chicken salad

calculated amount of nutrient — estimated amount of nutrient

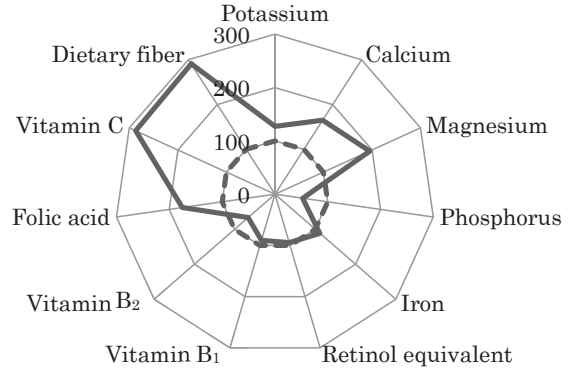


**Fig. 8** The comparative amount of nutrient estimated for those calculated per 100 g of the bagna cauda salad

calculated amount of nutrient — estimated amount of nutrient

coefficients in this study were relatively high may be due to the fact that this study restricted the analyses to only salad. That is to say, there are difficulties in judging the menu and estimating the amounts of ingredients from one-dimensional photographs of various dishes. Moreover, the relative nutritional balance instead of the amounts of nutrients was analyzed in this study.

In order to manage a healthy dietary life, it is necessary to estimate the nutritional balance of one’s meals. Howev-

er, there have been no successful reports of doing so using computer software without human support. Additional work will be required to further validate the effectiveness of this technique, and investigate its use for estimating the nutritional balance of not only salads but also for the analysis of main dishes and side dishes.

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