Imaging system for an objective assessment of the colour of potato crisps

Project proposal

Confidential

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Proposal for
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1. Introduction

For the crisp industry, the colour of the fried crisps is a very important quality parameter. Whether or not a load of potatoes will be accepted for processing depends to a great extend on the colour of the crisps. Furthermore, prices paid to the potato suppliers also depends on this quality aspect. Therefore, it is very important that the colour of fried crisps can be assessed in an accurate and objective way. In this project proposal, the research route for the development of an automated system to assess the colour of fried crisps objectively and accurately is worked out.

1.1 Existing way of assessing the colour of crisps

At the present, the colour of fried crisps is assessed by product experts. The fried crisps are compared with crisps on a colour card. On this card, crisps are pictured with different colours and divided on a colour scale from 1 (dark) to 9 (light). Humans are capable to detect small colour differences and other quality aspects like for instance the presence of cracks, skin and dark spots. However, the sensory evaluation by product experts is very subjective and depends on elements which have nothing to do with the quality of the product. This subjectivity introduces discrepancies between the assessments of a certain batch of crisps by different product experts. It is often the reason for discussions about the colour between potato suppliers and the processing industry.
To overcome the problem of subjectivity, colour measurement systems like the Agtron or Hunterlab are used. However, these systems only measure mean values of the colour. For many products, like crisps, the mean value will be not sufficient to determine the quality because colour heterogeneity is also a very important quality parameter. Furthermore, for a reliable and reproducible colour measurement, the object to be measured has to be flat and fit into the apparatus. For crisps this is certainly not the case. Therefore, the commercial available colour measurement systems are not suitable to assess the colour of fried crisps.
It turns out that for the crisp industry, there is a strong need for instrumental method to assess the colour of the crisps objectively.

1.2 New standard method for the assessment of the frying colour

The Dutch Agrotechnological Research Institute (ATO-DLO) has successfully developed a system for an objective assessment of the colour of French fries, which is also one of the most important quality parameters for the potato processing industry. Besides the colour, the system yields information about colour heterogeneity and length of the French fries and can be used as a standard. It is developed for the Dutch Association for the Potato Processing Industry (VAVI).
The system consists of a lighting chamber in which a plate with twenty French fries are placed. The fries are illuminated homogeneously with constant intensity. Images of the fries are taken with a colour camera while a personal computer with special imaging hardware is used to process the images and to calculate the colour of the French fries.
The assessment of the colour of crisps is similar to the assessment of the colour of French fries. Nowadays, the colour of the fries is still assessed by product experts and is based on the USDA colour card. The frying colour index is a weighted mean of twenty French fries and lies between

0 (light)and 6 (dark). As in the crisp industry, the evaluation of the quality suffers from the problem of subjectivity. However, this problem is solved now due to the new system.
The colour information of the images with fries is directly related to the sensorial colour values assessed by ATO-DLO product experts. It is therefore that the measuring system can be used directly by the potato processing industry, without introducing any changes into the present way of characterising potato quality.

2. Goal of the project

The goal of the research project, worked out in this proposal, is to develop an imaging system for an accurate and objective assessment of the colour of fried crisps. The system can be used as a standard and is suitable for use in the laboratory. The value of the colour yield by the system is equivalent to the colour value used nowadays by the product experts and crisp industry. This means that the system yields a mean colour of a batch of crisps with a value between 1 (dark) and 9 (light). Therefore, the system can be used immediately in the laboratory.
Besides the colour, the system yields information about other important quality parameters such as the heterogeneity of the colour and shape of the crisps as well as the presence of dark and green areas. Within 5 to 10 minutes approximately 800 gram must be analysed.

The frying colour system for French fries, developed by ATO-DLO for by the VAVI, will be used as a basis. This system is owned by the VAVI. To be able to make use of the knowledge and expertise gained during the development of this system, it is suggested that Croky Holland (Deventer) becomes a member of the VAVI.

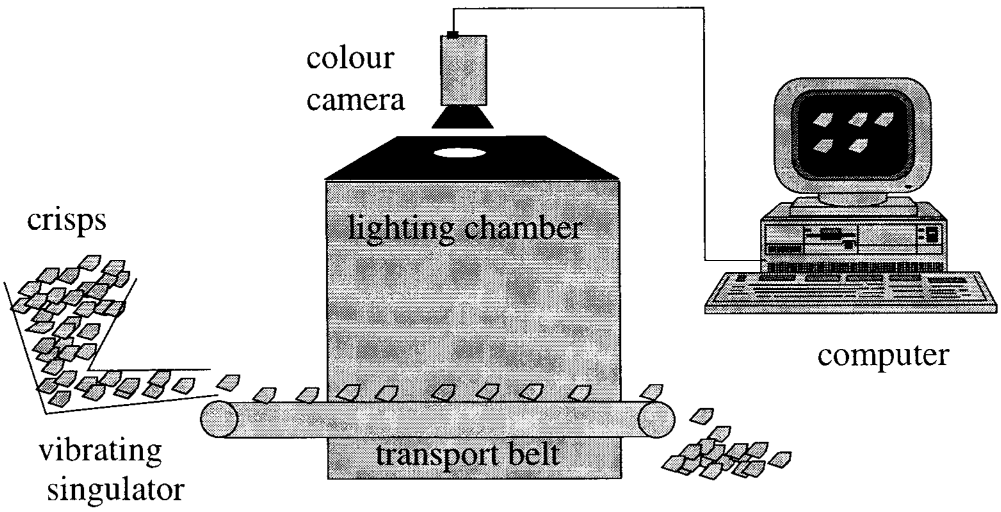
3. Parts of the colour assessment system

The imaging system consists basically out of two parts:
A) Transportation, lighting and image shooting of the fried crisps
B) Analysis of the grabbed images.

3.1 Transportation, lighting and image shooting of the fried crisps

Within approximately 5 minutes, 800 gram (corresponding to approximately 600 pieces) of crisps must be analysed by the system. This implies that the imaging system has to be equipped with a transportation system so the individual pieces of the crisps passes the camera and lighting chamber automatically. To obtain as much as possible information about the quality of the batch, each crisp is analysed separately.
Therefore, the hardware equipment for the system consists of four parts, which are schematically drawn in the figure.

- *Colour camera*
  A calibrated 3-CCD color camera is used to take colour images of the passing crisps. Small differences in camera settings between different sessions is calibrated for.
- *Lighting chamber*
  In this chamber, images are taken of the crisps under stable, uniform and calibrated circumstances. High-frequency TL-lamps are used which are fed back so a constant illumination is obtained. Furthermore, the size of the chamber, position of the lamps and diffusers are important to obtain homogeneous illumination. Small differences in illumination between different sessions is calibrated for.
- *Transporting belt*
  The individual crisps are moved under through the colour camera by means of a transporting belt, moving at a constant speed.
- *Vibrating singulator*
  This device makes sure that the pieces of the batch crisps are positioned at the transportation belt, separated from each other. At the front of the vibrating singulator, the total batch of crisps is loaded, while at the end the crisps are profided one at a time to the transport belt.



3.2 Analysis of the grabbed images

When an image from a crisp is taken, it is analysed by means of a personal computer. From the image, the quality parameters for the batch as well as for the individual crisps are calculated. An image consists of a two dimensional matrix of so called pixels. The spatial resolution of one pixel is about 0.5 mm^2. This implies that a crisp can be represented by ca. 1000 pixels. Every pixel contains colour information of the crisp.
Images are processed by means of image analysis techniques to extract the relevant information about the quality of the crisp. By means of advanced statistical techniques and / or neural networks, a model is developed which relates this information to the colour of the crisps, such as assessed by the product experts. Furthermore, models are developed for the assessment of additional quality parameters, such as the presence of greening, skin, and dark spots. Also shape parameters are calculated to detect e.g. broken crisps.

Important for a well functioning of the system is the quality of the model which relates the information of the images with the colour as assessed by product experts. Experienced product experts from ATO-DLO will be used as a leading guide for the model. These product experts give courses in quality assessments and developed the colour card for crisps, as used now by the crisp industry. For the development of a good robust model, several experiments with ATO-DLO product experts have to be performed and influences of the following features have to be studied

- *Different potato race and the colour of the flesh of raw potatoes*
  Product experts can assess the crisps colour which is only due to the frying of the potato slices, thereby neglecting the colour of the raw potato. The camera sees just one colour for each pixel. To what extend different race influence the colour and the model has to be studied.
- *Curly shape of the crisps*
  In contrast to French fries have crisps curly shapes. This introduces light shades on the crisps and making a homogenous illumination difficult. Furthermore, due to the curly shapes, different parts of the same crisp are seen under different angles by the camera and at different distances. These effects have to be incorporated into the model.
- *Thickness of the crisps and the degree of being diaphanous*
  Fried crisps are so thin that the colour of the transporting belt will be seen through the crisps. Due to the curliness this effect will not be homogeneously distributed over the crisp. The colour of the transporting belt will therefore be seen by the camera through the crisps. In what way this effect has to be corrected for, has to be studied.
- *Fat bubbles*
  Product experts take into account the presence of fat bubbles, which appear in the image as areas having a somewhat lighter colour as its surroundings. These effects on the model have to be studied.

4. Planning, duration and costs of the project

The project can be divided into three parts

1. *Development and building of the lighting chamber, transportation system and vibrating singling device.*
   During this part of the project a research will be performed for finding the best way to construct the lighting chamber and transportation unit. Thereafter, the equipment will be bought and the prototype of the system will be build.
2. *Development of model which relates the image characteristics of the crisps to the quality parameters colour, colour heterogeneity, dark spots, greening and shape.*
   This part of the project can be performed partly simultaneously with part 1, making use of the equipment from ATO-DLO. During this part, the model will be developed and influences as mentioned above will be studied and incorporated into the model. During this stage, many images of crisps of different qualities and race will be taken. The relevant information will be extracted from the colour image and related to the sensorial assessment of the ATO-DLO product experts. Also a manual will be written.
3. *Test, validation and handing-over of the system.*
   During this stage the system will be tested and validated intensively. Thereafter the system will be handed over to Westimex and installed.

4.1 Time planning and costs of the different fases

The duration of the project is planned for one year. In the table below, the time planning of the different fases are shown schematically.

fase/ month	1	2	3	4	5	6	7	8	9	10	11	12
1: hardware												
2: model												
3: installation												

Time planning, required labour time and labour costst are shown for the different fases in the table below. Also the required materials and costs are shown. The prices mentioned are in Dutch guilders, according to the ATO-DLO rates in 1997.

fase	duration (months)	labour (months)	labour costs (fl)	material
1: Developing and building of the hardware equipment	8	0.3 (SR) 3 (R) 2.5 (TA)	7200 53250 27825 total 88275	Lighting chamber and transport belt (ca fl 15000) Vibrating singulator (ca fl 25000) 3CCD colour camera (fl 10000) Computer (fl 5000) framegrabber (fl 6000) total 61000
2: Development model	10	1.5 (SR) 8 (R) 1 (PE)	36000 142000 11130 total 189130	
3: Test, validation, handing-over and installing	2	0.2 (SR) 1 (R) 0.5 (TA)	4800 17750 5565 total 28115	

SR: senior researcher (fl 24000 per month)
R: researcher (fl 17750 per month)
TA: technical assistant /
PE: product experts (fl 11130 per month)

4.2 Summary of the total costs of the project

Labour

1 year	researcher	fl 213000
2 months	senior researcher	fl 48000
4 months	technical assistant	fl 44520
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total labour		fl 305520

Materials

lightning chamber with transport belt	fl 15000
vibrating singulator	fl 25000
computer	fl 5000
camera	fl 10000
framegrabber	fl 6000
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total materials	fl 61000

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total costs of the project	fl 366520