An Roinn Talmhaíochta,
Bia agus Mara
Department of Agriculture,
Food and the Marine

2019RP316 - Validation of a Combined Vision and Robot Test Platform for Commercialisation

Final Report

This project was funded under the Department of Agriculture, Food and the Marine Competitive Funding Programme.

SUMMARY

Ireland exports around 13% of the worlds infant formula (IF). Reconstitution of IF powder is governed by a number of factors including, the manufacturing process, the functionality of the starting ingredients and the preparation instructions given by the manufacturer, these steps are usually determined by regulatory bodies. The final step that influences reconstitution quality of IF powder is the different motions and speeds applied by the primary caregiver during bottle preparation. Existing industry methodologies used to evaluate the physical properties of the reconstituted product tend to be subjective and vary depending on the person completing the test. Hence the objectives of this project was to evaluate the application of collaborative robot to prepare infant formula. Develop and investigate a suitable vision system for identifying and measuring the presence and type of white particles (unhydrated powder particles / flecks) present. Two vision protocols (one without and one with UV lighting) were programmed using the programming language Python and evaluated.

A single arm collaborative robot was successfully programmed to add spoons of powder to an infant bottle and perform an "up and down" or "circular" shake motion. A UV lamp in combination with a UV detecting camera was utilized to identify if the application of UV could illustrate different particle types i.e. flecks in comparison to particles that are unhydrated. The vision system used in combination with machine learning demonstrated the most potential for identifying flecks. Additional industry samples are required to validate the system. A new method was successfully developed using computer vision for accurately measuring the "wetting time" of IF.

The project has successfully developed two automated vision methods that can be used to consistently evaluate the reconstitution properties of IF. Results from this project are being used as part of a Enterprise Ireland commercialization fund proposal.

KEYWORDS

Robotics; Infant formula; Vision; Flecking

ACRONYM	VISIOBOT
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Section 1 - Research Approach & Results

Start Date

01 August 2020

End Date

30 November 2021

Research Programme

Food Institutional Research Measure

TRL Scale

TRL 5: Technology validated in relevant environment

NRPE Priority area

Manufacturing Competitiveness

Total DAFM Award

€80,177.44

Total Project Expenditure

€79,158.33

Rationale for undertaking the Research

Reconstituted infant formula (IF) quality:
The end-users, IF companies both native and international as well as Irish dairy ingredient companies require an accurate, repeatable and robust method for determining reconstitution properties of finished IF powder. Additional scenarios where this technology is required include when evaluating formulations that have a new ingredient substitution that may alter the final powder reconstitution quality.
Number of Methods:
Research methods used for characterizing the reconstitution properties of IF vary from complex rheometry to NMR relaxometry, bulk density and particle size. There are numerous lab based methods for describing steps in the reconstitution process but none that give a combined cohesive single result for the undesirable properties that industry receive complaints about i.e. flecks.
Standardization:
Industrial reconstitution methodologies comprise of an individual reconstituting the IF under conditions that are not repeatable (different speeds and patterns of motion) and performing a visual inspection and evaluation of the bottle followed by decanting the IF emulsion onto filter paper and using a subjective scoring system to score the filter paper (with a number that denotes the severity of flecks present).Although training is given to process technicians, the score given can vary depending on a technician interpretation of the sample.
Consumer expectation: consumers expect to be able to add water to infant formula (IF) and observe are constituted liquid that resembles milk. Undesirable changes in stability of a reconstituted IF emulsion e.g. flecks in IF, can have detrimental effects on a manufactures brand confidence.

Methodology

The VisioBot project produced infant formula (IF) powders with different final powder functionality; the wet mix properties and the processing conditions used to develop these IF powders were measured and monitored (Task 1).

The IF powders were characterized using standard reconstitution protocols (e.g. wetting time, insoluble index, bulk density) as well as compositional methodologies (e.g. protein, moisture, free fat) used in industry and research, as a benchmarking tool for comparison with the test platform. The test platform comprised of an one-arm collaborative robot (cobot) for controlled reconstitution of IF. Firstly, the cobot was programmed to shake the bottle. The prepared samples were tested for colour, particle size and dry matter content (total solids) (Task 2).

A suitable camera and filter were identified, chosen and integrated with the cobot for development of a vision protocol for identification and measurement of white flecks. Two methods were evaluated for fleck detection, 1.) analysis of fleck detection without UV light and 2.) using UV lighting with a deep learning method.

Wetting time is an important powder specification parameter for infant formula manufacturers. Therefore a high speed camera was used to develop a vision method for measuring the time taken for the powder to disappear below the surface of the water. Finally, to confirm the presence of flecks in the tested samples, particle size and confocal laser scanning microscopy (CLSM) was completed on the reconstituted liquid sample and infant formula powder (Task 3).

The overarching goal of this project is to bring the technology to a point where it is eligible for Enterprise Ireland (EI) commercialization supports, hence regular discussions were scheduled with the Teagasc Technology Transfer Office (Task 4).

Project Results

Main Results:

- Six infant formula (IF) were produced (three in the Teagasc pilot and three in the MTL pilot plant). Samples produced in the Teagasc pilot plant had drastically poor reconstitution properties but flecks were not observed unlike the samples produced in MTL where flecks were observed and confirmed using CLSM.
- Prior to selection of an appropriate camera, a short review on white flecks was prepared to help in identifying a suitable vision camera. A 6.3MP UV-detecting Camera, was sourced from Ehd imaging along with a 340nm Bandpass filter for vision analysis and a UV lamp.
- A single arm collaborative robot was successfully programmed to add spoons of powder to an infant bottle and perform an "up and down" or "circular" shake motion.
- Utilization of a UV lamp to cause particles that are flecks to fluoresce in comparison to particles that are not hydrated was evaluated. Two vision protocols (one without and with UV lighting) were programmed using Python and evaluated.
- A new method was successfully developed using computer vision (Background subtraction algorithm) for accurately measuring the "wetting time" of IF.
- The research officer completed the UCC Sprint accelerator programme, (support early-stage start-ups and entrepreneurs), it focuses on the commercialisation of technologies and routes to market.

Conclusions:

"Determination of particles using a vision method without UV lighting":

Advantages:

1. The particles are clearly visible and illuminate more (without increasing the Gain in the camera) under the normal lighting conditions.

Disadvantages:

1. There is a lot more glare captured at the sides of the bottle making detection harder for the algorithm at the sides of the bottle.

Fleck detection with UV light:

Advantages:

1. The algorithm is highly adaptive and no parameters are set for fleck detection i.e. it automatically conducts the hit and trial for optimum values from a range of values and picks the best result.
2. There is reduced glare at the sides of the bottle due to band pass filter.

Disadvantages

1. Most things illuminating under normal lighting conditions still tend to be illuminated under UV light(except there is a reduction in brightness).

   Overall, additional real-world samples from industry are required to validate the "fleck detection using UV light method.

   The "wetting time" method developed is significantly more accurate compared to its commercial counterpart. Currently this method is being completed by eye using a stop watch. Powders which have a small wetting time specification e.g. whey protein isolate in particular (must disappear below the surface of the water within 13 seconds) are prone to human error. The method developed in this project is significantly more accurate.

   Finally, using a one arm cobot in combination with the UV camera chosen and vision methodologies developed in this project, sufficient information was collected to allow the project coordinator to submit an Enterprise Ireland commercialization fund proposal in June 2020. The evaluators of the proposals declined the proposal but asked for a re-submission. The additional requested information is currently being prepared for a resubmission.

Section 2 - Research Outputs

Summary of Project Findings

Two methods were evaluated for fleck detection,

1. Analysis of Fleck detection without the use of UV light, the reconstituted bottle is placed in a light box under normal lighting conditions (visible spectrum) while images are taken of the particles sticking to the sides of the bottle using a camera (without any bandpass filter).
2. Image Analysis for Fleck detection using UV light. The reconstituted bottle is placed in a light box under UV lighting while images are taken of the flecks sticking to the sides of the bottle using a UV camera (with a bandpass filter).
3. An additional method was developed for accurately measuring the "wetting time" of infant formula powder.

These methods are of benefit for dairy industry and in particular the infant formula (IF) industry for the following reasons:

Industry:

1. White particles which have not been reconstituted, are an undesirable parameter of reconstituted IF for the consumer. Detection and identification of white particles visible at the top of an infant bottle allow processors to understand the origins of the parameter and hence where potentially the process can be optimized to ensure the presence of the particles is limited. When the vision technique is used in combination with the cobot it also allows the processor to understand if the parameter is process related or consumer related i.e. the consumer has not prepared the bottle appropriately.

2. IF processors that produce IF for third party manufacturers who then re-brand product, using this automated "wetting time" method can ensure their product consistently and more accurately meets the wetting time described in the powder specification.
   Research:
3. There are few publications / projects using computer vision in dairy science.
   Consumer:
4. Overall, these methods ensure that IF processors product meets the quality expectations of the consumer.

Summary of Staff Outputs

Research Output	Male	Female	Total Number
Other/Temporary	1	0	1

Summary of Academic Outputs

Research Outputs	Total Number	Details
No Response	0	Due to Covid-19, it was not possible to disseminate this project compared to what is normally done. The Project Co-Ordinator was also on maternity leave for 6 months of the project. Finally, some of the learnings and results from this project are being used as part of an EI commercialisation fund proposal and hence cannot at present be published.

Intellectual Property

Regarding the automated "wetting time" method developed, an invention disclosure form will be put inplace to document the entire process and a software disclosure form. Additional support has been sought from the Teagasc Technology Transfer office.

Summary of other Project Outputs

Project Outputs	Details	Total Number
New Processes	Vision method developed for measuring wetting time	1
New Technology	Integration of camera and filter with single arm cobot platform for preparing infant formula using "up and down" and "swirl" shake motions for determining flecks from unhydrated particles as well as the numerical value for the quantity of flecks present.	1

Potential Impact related to Policy, Practice and Other Impacts

Impact	Details
Industry	The new methods developed for evaluating if white particles are unhydrated material or flecks, allows infant formula processers to accurately determine the reconstitution quality of the powder.

Dissemination Activities

Activity	Details
Other	The new methods developed for evaluating if white particles are unhydrated material or flecks, allows infant formula processers to accurately determine the reconstitution quality of the powder.

Knowledge Transfer Activities

Identify knowledge outputs generated during this project.	▪ Until this project, limited knowledge existed on the application of computer vision in dairy product applications and in particular infant formula. Hence de-novo knowledge was created around appropriate lighting to use for capturing the images. ▪ Programming of a cobot to perform shake motions using a single arm collaborative robot. ▪ Selection and use of vision algorithms for detection of white and fleck particles. ▪ A new method was developed to accurately measure "wetting time" of infant formula powders.
Identify any knowledge transfer activities executed within the project.	Due to Covid-19 restrictions and the short duration of the project (1year), it was not possible to complete knowledge transfer activities. The research officer on the project completed the KTI- Knowledge Transfer Ireland hosted "Lean Start-up training course", as part of this training he developed a "Business Model Canvas" which was presented on day three of the training and the UCC Sprint accelerator programme.
List any impacts resulting from the knowledge transferred during the project.	The learnings from the "Lean Start-up training course" i.e. the business model canvas was included as part of the EI commercialisation fund proposal.

Section 3 - Leveraging, Future Strategies & Reference

Leveraging Metrics

Type of Funding Resource	Funding €	Summary
Other	€15,000.00	In October 2021, the project coordinator applied to the internal Teagasc Call – "Start-Fund" and was successfully awarded the fund in November 2021. This funding is for research with commercialization potential, which requires additional data/validation.

Future Strategies

The START project is currently coming to a conclusion. This project was used to hire a consultant to address the queries relating to the business case of a potential spin-out company raised by the evaluators from the initial Enterprise Ireland commercialization fund proposal. The START project yielded positive results and enough information for the preparation of a re-submission for commercialization funding to Enterprise Ireland. This resubmission is planned for November 2022.

Project Publications

Due to the commercial potential of the project, no peer reviewed publications were submitted. There is one manuscript based on the infant formula powder properties arising from the MTL pilot plant work under preparation.