– *The proof of the pudding is in the eating*
– *The proof of technology is in its use (The engineer's parallel)*

New Vision Technology for Multidimensional Quality Monitoring of Continuous Frying of Meat

Industrial Vision Day

DTU Informatics, 28 May 2008

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Food Production Engineering
National Food Institute

Technical University of Denmark

Innovative Solutions

Vision technology in food processes

- The trained process operator plays a key role in today's food industry. His or her ability to judge processes such as continuous baking, roasting and frying processes by visual inspection is crucial.
  - However, the knowledge and skills of the process operator are not easily passed on to other operators
- Automation, as an alternative, has been slow, due to inadequate technology
  - In particular this concerns the technology for data acquisition and data reduction for making corrections to the process
- New project: ***New vision technology for multidimensional quality monitoring of food processes***
  - Goal: Investigate the potentials of vision technology and develop the technical/scientific basis for a widespread use in process control of continuous baking, roasting and frying processes.

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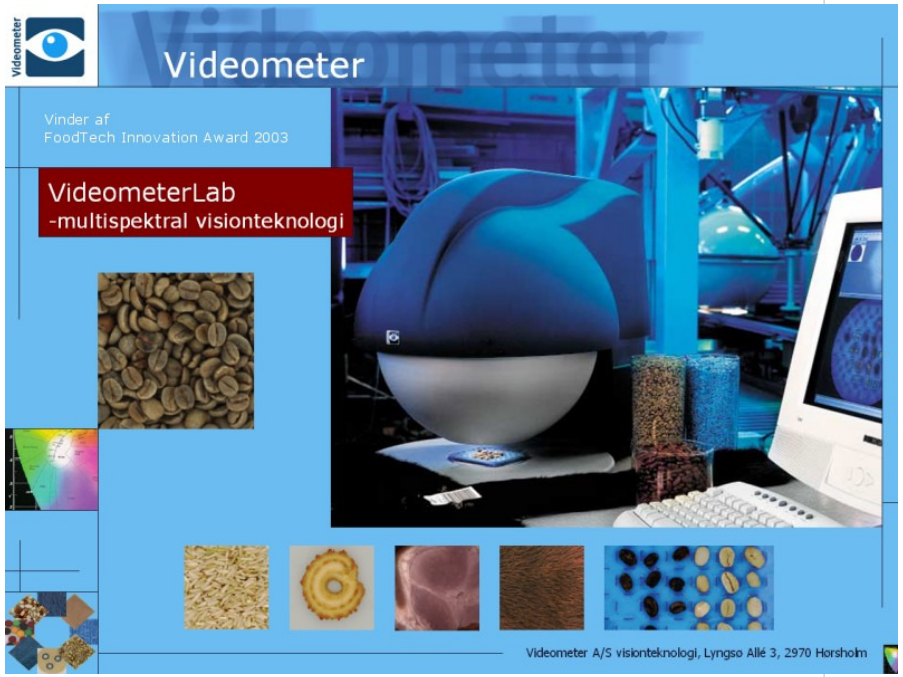
Videometer technology in food processes

- Technologies that measure on only small areas are inadequate (e.g. NIR)
- New vision technology:
  - the product is illuminated uniformly over a large area (50 cm^2)
  - at 18 specified wavelengths (LEDs)
  - may match much closer the visual judgment made by the trained process operator
  - nuances in browning and small specks can be detected



Adaption to on-line measurements is possible

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Monitoring continuous frying of meat

- A new process has been developed for continuous frying of minced meat
  - It is based on a piece of equipment invented at DTU and known as “the continuous wok”
  - It was investigated if vision technology could be used to detect minor differences in degree of frying and to assess the uniformity of the fried product
- Participants:
  - Søren Blond Daugaard, M.Sc. student
  - Jens Michael Carstensen, DTU Informatics (supevisor)
  - Bjørn Dissing, DTU Informatics (data analysis assistance)
  - Jens Adler-Nissen, National Food Institute (co-supervisor)

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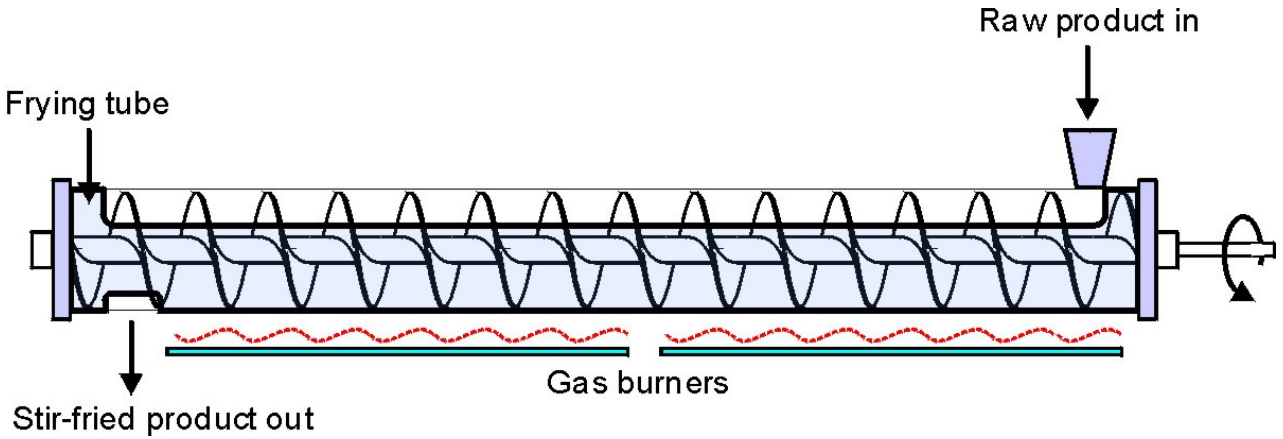
The continuous wok - principle



The continuous wok
(industrial prototype)

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The continuous wok – first prototype

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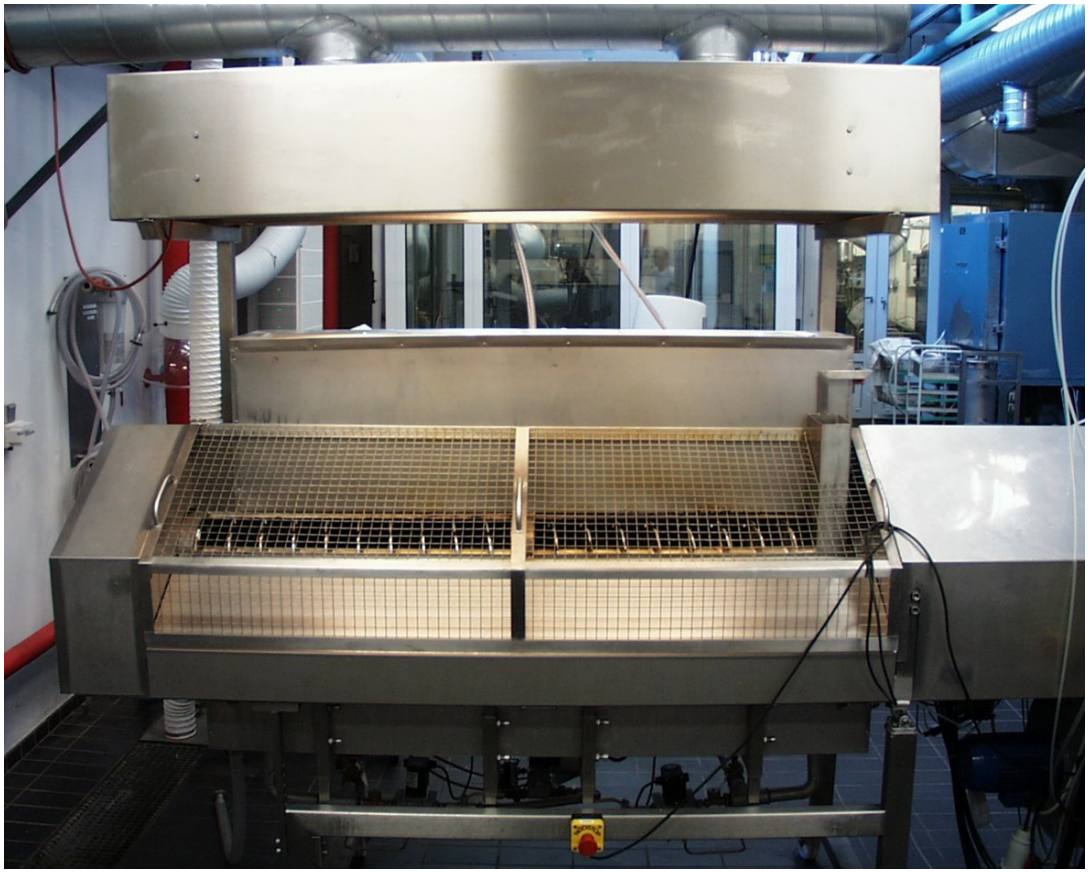
Commercial machine

Pilot plant prototype



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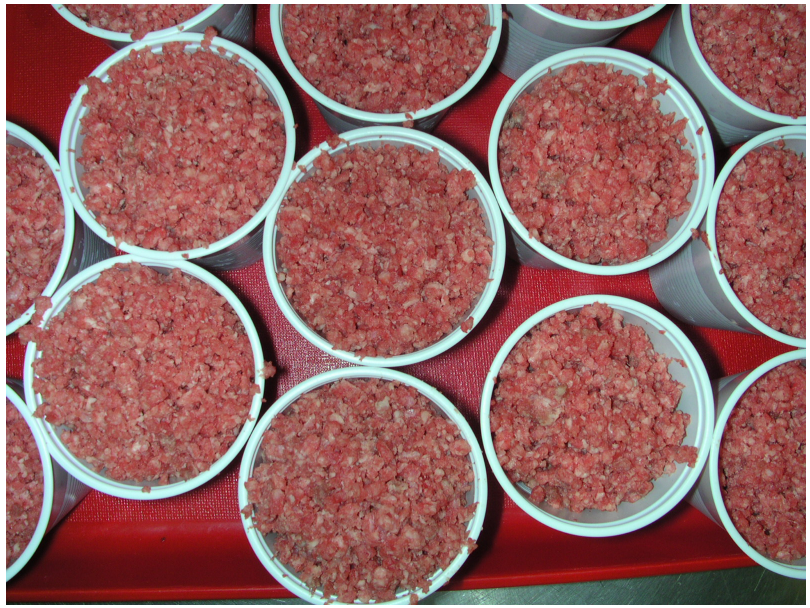
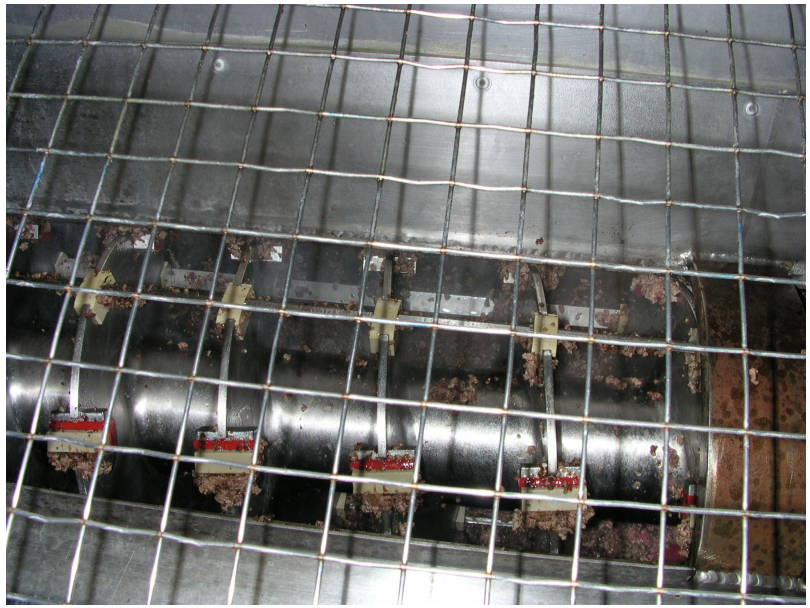
Also minced meat can be fried





Pre-treatment: Frozen, minced meat is broken into large lumps. The lumps are disintegrated in a conventional bowel chopper. The still frozen, free-flowing meat particles are immediatly transferred to the wok.

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Fried, minced meat in loose particles

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Minced meat – frying parameters

Class	120 s	160 s	200 s	240 s
200 C	Under	Under	Under	Under
225 C	Under	**Adequate**	**Adequate**	**Adequate**
250 C	**Adequate**	**Adequate**	**Adequate**	**Adequate**

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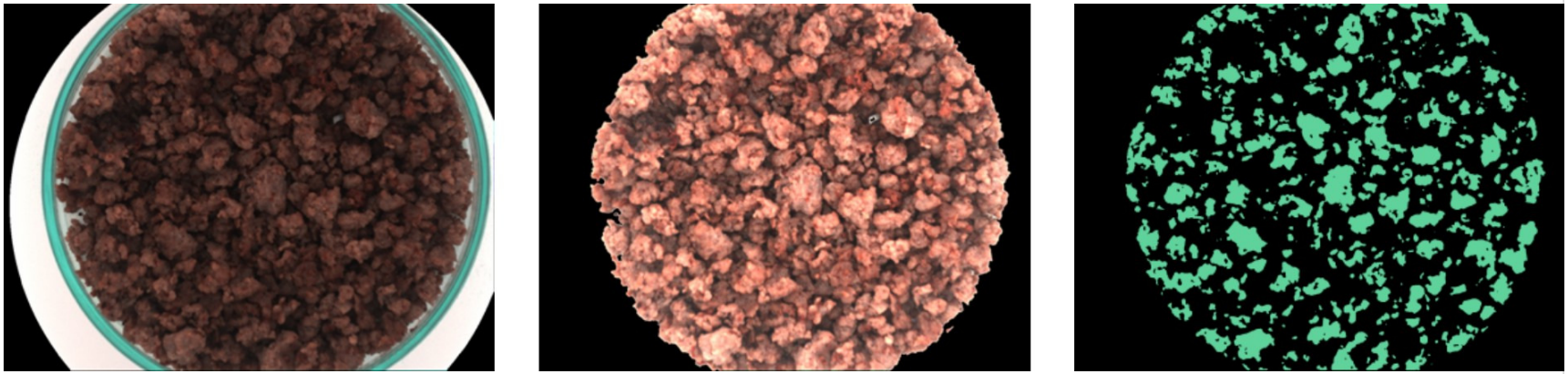
Image transformation

A B C



A: Original sample of fried minced meat

B: Image after removal of petri dish etc.

C: Identification of top-part of meat particles by h-dome segmentation at 700 nm. A suitable mask was obtained at an h-value of 35 and a threshold value of 7 (gray-scale 0 to 255)

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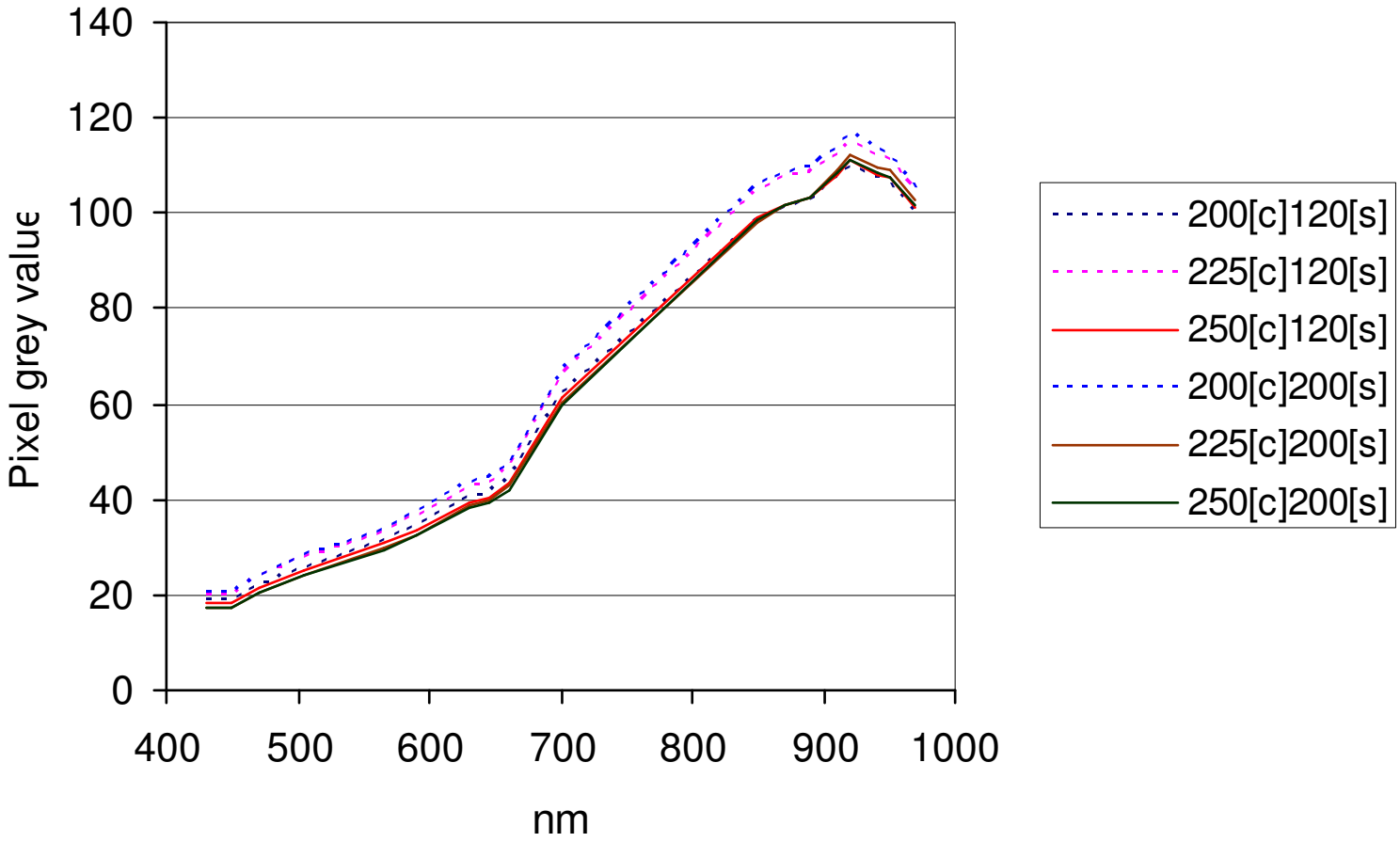
Selected spectra



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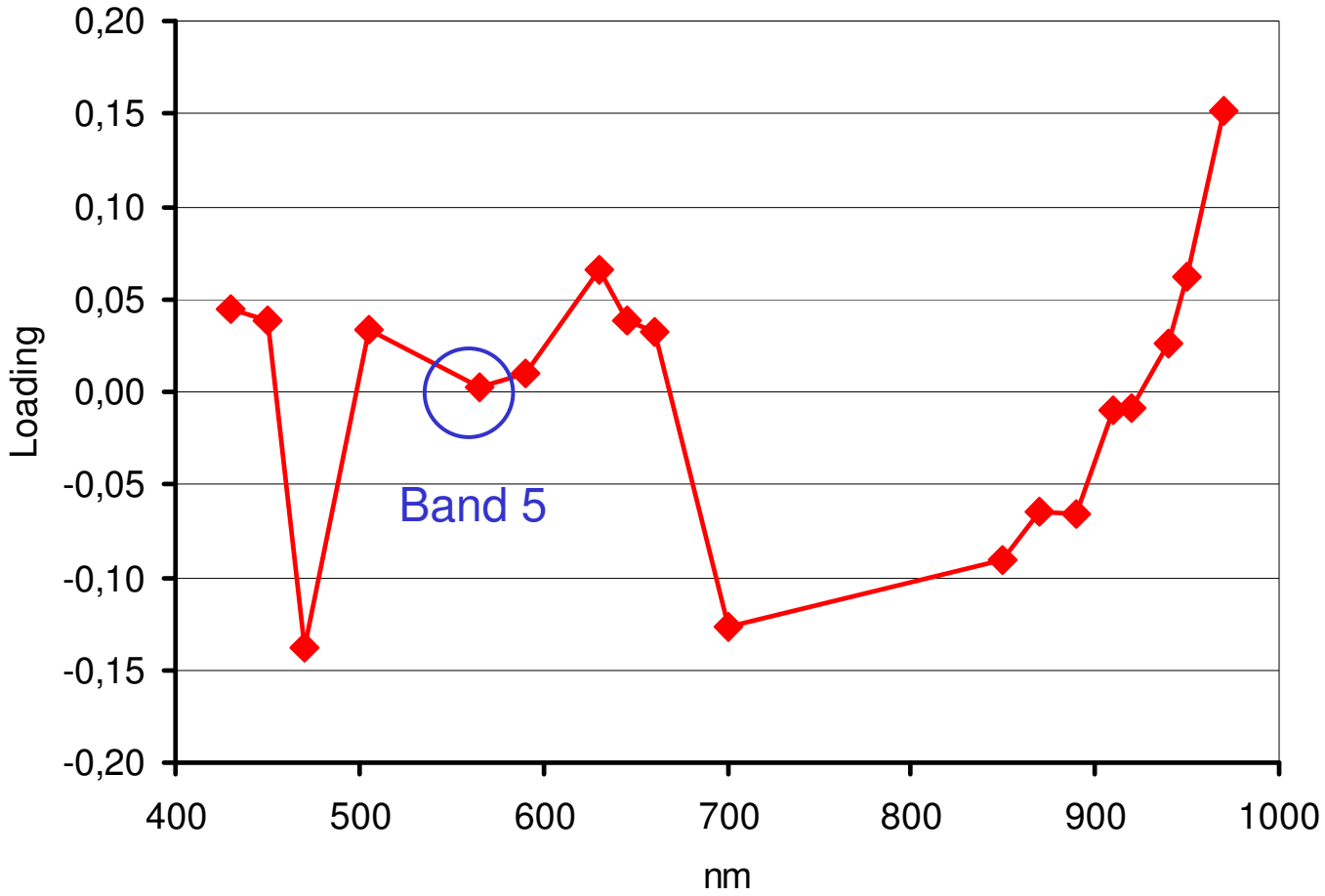
Loadings after CDA



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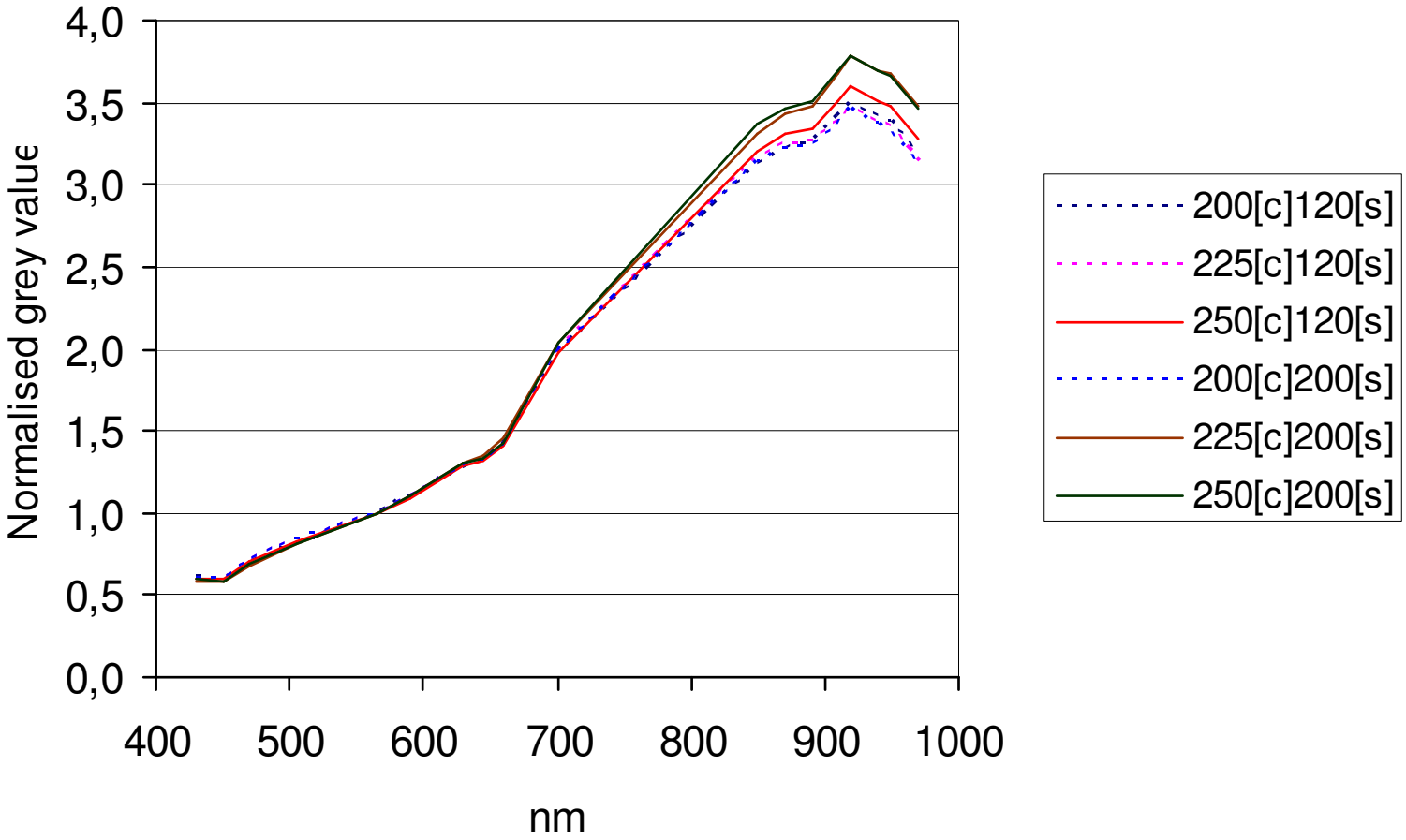
Selected spectra normalised (band 5)



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Frying treatment score: Projection of CDF

Average	120 s	160 s	200 s	240 s
200 C	-0,03	-0,87	-0,88	-1,02
225 C	-0,88	**1,46**	**0,71**	**0,00**
250 C	**0,12**	**0,60**	**0,29**	**0,58**

(Stand dev. from triplicates: 0,14)

The frying treatment score (FTS) is the mean value of the pixels in the pre-processed image (containing only meat) after projection of the 18 different grey scale spectral values of the pixels with the derived CDF in the CDA.

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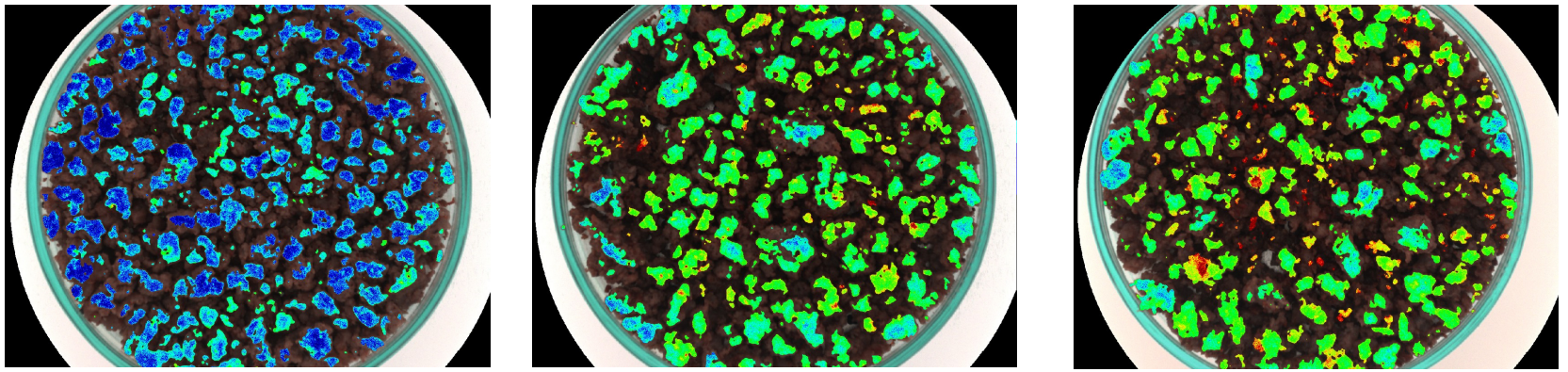
FTS is used for false colouring

A B C



A: 200 C, 160 s – Under-done
B: 225 C, 200 s – Adequate
C: 250 C, 160 s - Adequate

Note the uniformity of the frying treatment of the individual particles

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Agglutination experiments

- **Partial thawing** may induce agglutination during frying
  - Samples of the meat from the chopper were left to thaw at room temperature for 30 minutes, 1 hour and 30 minutes and 2 hours and 30 minutes, respectively
  - Each sample set included four samples processed at 225°C and 250°C and with frying times of 160 s and 240 s
- To create a physical measure of agglutination all samples were run through a strainer with 1.1 cm square holes immediately after frying
- The sizes and distribution of the meat particles were assessed by image analysis after h-dome segmentation at 850 nm and a connected component analysis
  - Pixel size is 0.077 mm × 0.077 mm

Agglutination

Thaw-ing time	Frying [s]	Tempe-rature [°C]	Strainer Loss [%]	Mean granule size [mm^2]	σ mean granule size [mm^2]	Avg. max. granule size [mm^2]	σ max. granule size [mm^2]
0,5 h	160	200	1,04	5,5	0,6	56,2	11,5
	240	200	0,00	4,8	0,5	49,6	5,7
	160	225	0,21	5,6	0,5	63,8	12,9
	240	225	0,94	6,4	0,2	69,0	88,0
1,5 h	160	200	1,88	5,4	0,5	80,8	34,0
	240	200	5,09	6,0	0,4	94,8	40,2
	160	225	2,40	5,6	0,5	84,9	35,6
	240	225	2,22	6,3	0,7	71,4	36,0
2,5 h	160	200	6,59	6,4	0,9	106,6	23,0
	240	200	6,65	7,2	0,6	183,4	84,2
	160	225	6,01	6,9	0,8	90,2	18,4
	240	225	6,63	6,8	0,7	109,6	33,9

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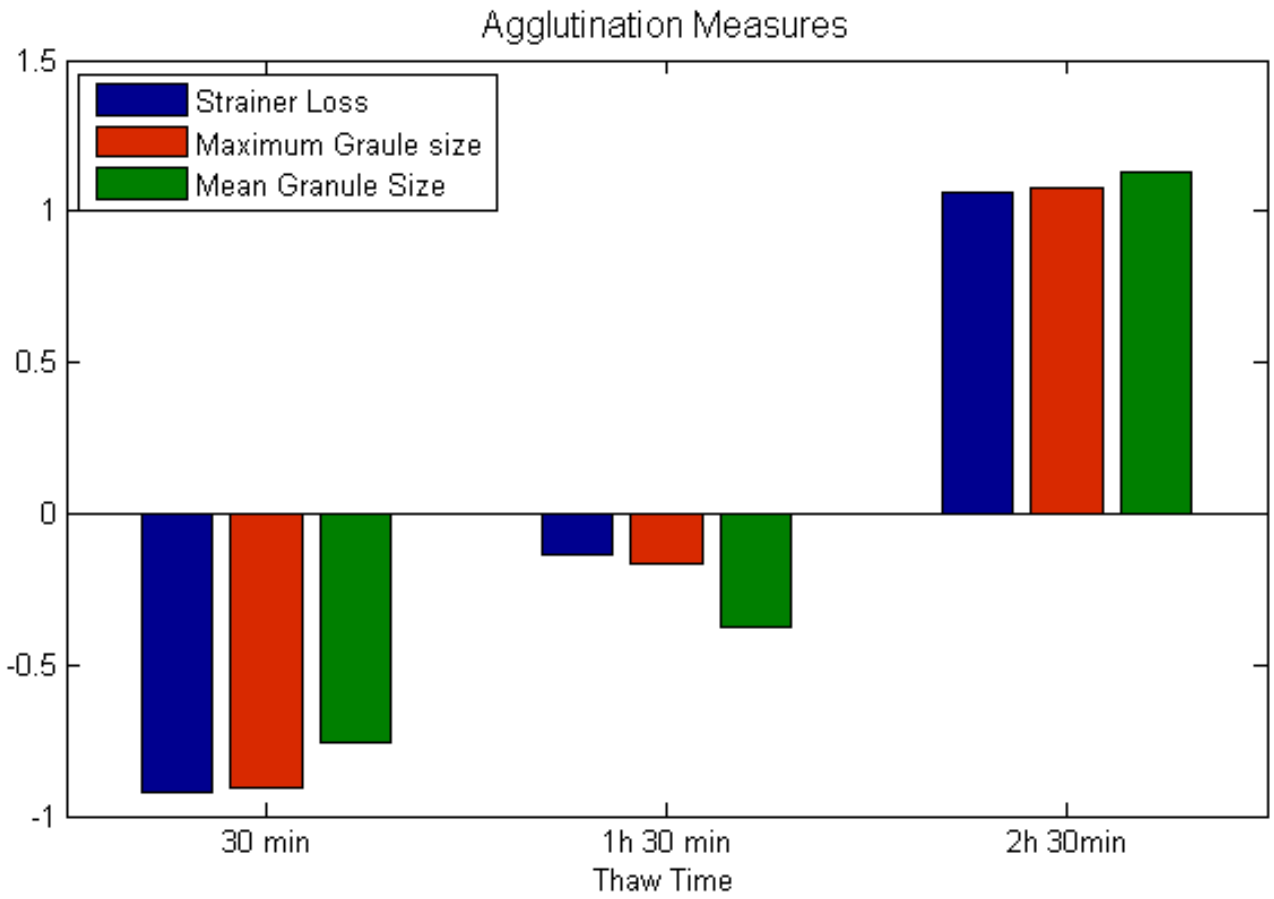
Image analysis predicts agglutination



Data have been normalized to zero mean and unit variance

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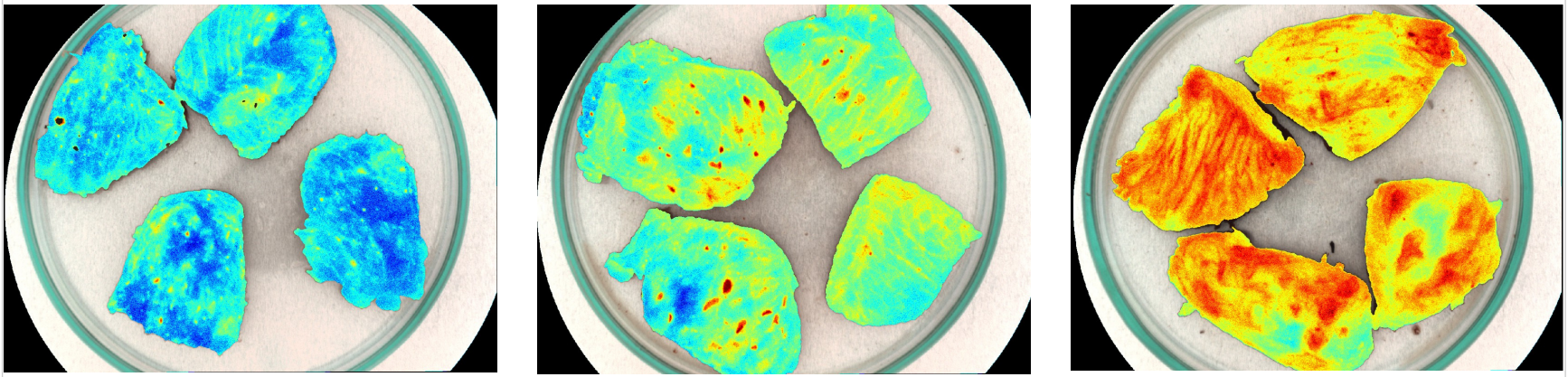
Diced Turkey – assessment of frying

Under-done | Done | Over-done



These results confirm the idea of using vision analysis as a substitute to the operator's visual inspection

Note the uniformity of the frying treatment

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Conclusion

- Vision analysis can predict the severity of the frying treatment, although with som variation
- Vision analysis is probably most promising with regard to assesment of the uniformity of the product after processing
- It should be investigated if the spectra can reveal quantitative information about the water content of the minced meat
- The work is pursued with other products (breakfast cereals) in a newly started Ph.D. project. This work is supported jointly by the Ministry of Food and DTU through the Ph.D. school, FOOD

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