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Recognition of Fish Species by Surface Pattern Classification of Skinned Fillets

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Zusammenfassung
Änderungen der Fischqualität gehen häufig mit Veränderungen im Aussehen und der Textur einher. Eine grobe Klassifizierung des Aussehens ist Teil der sensorischen Prüfung durch Experten, die zwar objektive, aber ungenaue Daten liefert. Bis jetzt gibt es keine instrumentellen Sensoren, deren Daten mit den Expertendaten für die Einschätzung des Aussehens korrelieren. Instrumentelle Farbmessungen spiegeln nur einen Teil des Aussehens wider. Das Ziel der hier vorgestellten Methode liegt in der Anpassung der unscharfen, aber umfassenden Kenntnisse von Experten an die Daten, die von Kamerasystemen geliefert werden. Die Eignung der Methode wird durch die Klassifizierung der Fischarten an enthäuteten Fischfilets durch die rechnergestützte Interpretation von Oberflächenmustern getestet.

Summary
Fish quality changes are usually connected with changing of appearance and texture. The assessment of appearance is a part of sensor evaluation, carried out by experts providing objective but inexact data. Up to now there is no instrumental sensor supplying data which correlate to the experts assessment data for appearance. Instrumental colour measurement mirrors only a part of appearance. The objective of the method presented here is to fit the experts inexact but wide knowledge with the data from cameras. A test for the suitability of the method is the classification of fish species from skinned fish fillets by a computer aided interpretation of surface patterns.

Introduction

An European project has recently been finalised. Within this project the whole range of methods for checking and evaluating quality of fresh fish, especially freshness, has been reviewed (*Olafsdottir* et al., 1998). Unfortunately, image analysis of surface pattern was not reviewed more closely. Commencing with observing changes during ripening of salted herring products we attempt to develop pattern recognition by computer vision (*Kroeger* and *Schubring*, 1997). The deterioration of seafood quality is manifested through changes in appearance, odour, flavour, colour, and/or texture. Taking this into account, observing the surface of skinned fillets and recognising the pattern of the myotomes should offer the ability to evaluate the quality and related changes. The first sensory changes that occur in fish during storage are concerned with appearance and texture. Furthermore changes in the composition of the fish pigments lead to surface/flesh discoloration. For example, white fish flesh changes from a light creamy colour to grey, the bright red hue of dark muscle becomes dull and brown (Church, 1998). This is the background for using colour grading of fish fillets as a novel application for computer vision in the fish processing industry. The solution to this task is that classification algorithms measures the colour in different areas. It also interprets the colour measurement based on the position of the measurement adjusting in that way for the natural accepted colour variation within the product (*Arnarson*, 1998). Furthermore surface defects can be detected using computer vision but this requires a two face inspection (*Arnarson* and *Khodabandehloo*, 1993). An excellent review on fish quality control by computer vision is given by *Pau* and *Olafson* (1991). The possibility to determine fat and connective tissue in fish muscle by means of image analysis has been recently published (*Borderias* et al., 1999). The objective of the investigations presented here is the analysis of surface pattern from fish fillets to identify species and quality states. Measurements and recordings of patterns were carried out by a digital image processing system using optical components aiding a resolution of the surface structure below the scale of myotomes.
Based on the results published so far (*Kroeger* and *Schubring*, 1997) the investigations were subjected to control the surface patterns of both the skin and meat side (surface removed from

the backbone) of several skinned fish species via computer vision. The results were checked for the possibility to differentiate between the species. Preliminary observations were performed concerning the influence of ice storage on the surface pattern using saithe fillet.

Materials and Methods

Fish samples

The investigation was performed on board the fishery research vessel „Walther Herwig III" during the 195th cruise. The captured fish were filleted and skinned after hauling pre rigor and immediately placed under the CCD camera for a recording of the pattern in a very preliminary state. The surface patterns of both skin and meat side (surface removed from the backbone) of skinned fillets were investigated. For all species at least 10 images from different fillets were recorded for later analysis. Images were taken from the anterior part of the fillet using both the range of the spine (meat side) or the lateral line (skin side). Preliminary investigation was performed to determine the influence of rigor mortis as well as freeze-thaw cycle using saithe. Due to this pictures were taken using fillet pre rigor (2 h) as well as after passing the rigor (72 h) and additionally, using post rigor deep-frozen fillet after it has been thawed following a 10 day frozen storage at – 24 °C. Altogether 320 images were processed. The fish species used for digital image processing are listed in Table 1.

Tab. 1 Fish species used for pattern recognition

No	Species	Scientific name	Catching ground
1	Cod	Gadus morhua	NW Faroe Island
2	Saithe	Pollachius virens	W Shetlands
3	Hake	Merluccius merluccius	W Shetlands
4	Haddock	Melanogrammus aeglefinus	NW Faroe Island
5	Whiting	Merlangius merlangus	E Faroe Island
6	Herring	Clupea harengus	E Faroe Islandr
7	Mackerel	Scomber scombrus	W Shetlands
8	Horse mackerel	Trachurus trachurus	E Faroe Island
9	Plaice	Pleuronectes platessa	E Faroe Island
10	American plaice	Hippoglossoides platessoides	N Faroe Island
11	Dab	Limanda limanda	NW Faroe Island
12	Ocean perch	Sebastes marinus	W Shetlands
13	Grenadier	Macrurus rupestris	W Shetlands
14	Atlantic halibut	Hippoglossus hippoglossus	E Faroe Island
15	Greenland halibut	Reinhardtius hippoglossoides	W Faroe Island
16	Dogfish	Squalus acanthias	Mykiness
17	Greater forkbeard	Phycis blennoides	Bill Bailey Bank
18	Tusk	Brosme brosme	W Shetlands
19	Ling	Molva molva	N Faroe Island
20	Blue mouth	Helicolenus dactylopterus	N Faroe Island
21	Atlantic catfish	Anarhichas lupus	Mykiness
22	Spotted sea cat	Anarhichas minor	N Faroe Island
23	Grey gurnard	Trigla gurnardus	N Shetlands
24	Rabbit fish	Chimaera monstrosa	N Faroe Island

Image processing

Image recording and processing were carried out by a system consisting of low cost hardware components and software tools based on effective numerical algorithms. The main components were

1/2" CCD camera Hitachi KP-M1 (resolution 752 x 582)
Lens Pentax Cosmicar 1:1.8, f = 25 mm.
Distance sensor - fillet surface 110 mm
Framegrabber ELTEC PC-EYE 1.
Illumination system based on bulbs
Image processing software heurisko

For a large number of special problems software tools had to be developed.

Theoretical approach

Fish flesh itself is contractile muscle. It comprises specialised cells or fibres containing thick and thin filament which interact with one another. They produce the contraction and relaxation required for movement of the animal. In all animals these muscle cells or fibres are arranged parallel to one another and are held together by connective tissue. In mammals and birds this membrane is connected to the tendons. The connective tissue also anchors the muscle cells to the skeleton of the animal. However, in fish a different arrangement of muscle is found. The cells are bound together one cell deep to form segments or myotomes of muscle. These bundles of muscle cells are shaped like the letter „W" and are oriented across the mid-plane of the fish with the central parts directed towards the head of the animal. The ends of the cells are attached to sheets of connective tissue called „Myocommata" which separate one block of myotomes from another. In comparison to mammalian and avian muscle cells, those of fish are short, generally less than 20 mm (*Schubring* and *Sandau*, 1989; *Mackie*, 1997). The myotome as a bundle of parallel arranged cylindrical myofibrills have as a first approximation a cylindrical structure (*Keener* and *Sneyd*, 1998). They are combined along their axes and generate linear surface patterns by changing the surface profile in the binding areas. The patterns of myotomes are characteristic for the different species and are fluctuating depending on physical and chemical influences.

The greylevel pattern of the myotomes recorded in the images behave as periodic waves. We make the assumption that greylevels are proportional to the depth of the surface profile. The profile depth and the wavelength of the arranged myotomes depend on the number of myofibrils and of their state of binding. The total pattern is interpreted as a system of decoupled objects in definite binding states arranged on a square lattice. By help of analysis of linear symmetry of the single objects and their binding states the micro patterns of the images are classified.

Evaluation procedure

Objects within the images have to be connected to the local diameter of myotomes or the local number of myofibrils and

the local binding state. A link between images and real biologic quantities is given by the analysis of orientation of the local patterns. Due to this investigations on existence of linear symmetry within a local neighbourhood for all the pixels were carried out (*Bigün* and *Granlund*, 1987). The local state of symmetry was classified by a number (coherency).

As a first step the scalar greylevel images were transformed into vector images by forming gradients. The gradients have the direction of maximum greylevel variations and perpendicular to the lines of profiles.

$$g(\vec{r}) \Rightarrow \nabla g(\vec{r}) = (\partial g(\vec{r})/\partial x, \partial g(\vec{r})/\partial y) \quad (1)$$

$g(\vec{r})$ greylevel at point $\vec{r}$

$\vec{r}$ image vector with components x,y

From the vector image the mean local orientation of the pattern is extracted by designing a structure tensor (*Jähne*, 1997):

$$\Lambda'(\vec{r}) = \int_U \nabla g(\vec{r}) \nabla g^T(\vec{r}) d\vec{r} \quad (2)$$

The numerical realisation of the structure tensor is carried out by the product of the vector image and a window function for all the pixels and by the integration over the neighbourhood:

$$\Lambda'(\vec{r}) = \int_{-\infty}^{+\infty} h(\vec{r} - \vec{r}') \nabla g(\vec{r}') \nabla g^T(\vec{r}') d\vec{r} \quad (3)$$

with components

$$\lambda'_{mn} = \int h(\vec{r} - \vec{r}') \partial g(\vec{r}')/\partial r_m \partial g(\vec{r}')/\partial r_n d\vec{r}' \quad (4)$$

Solving the eigenvalue problem (*Courant* and *Hilbert*, 1968) for the structure tensor an expectation value is found for the mean orientation within the neighbourhood U. By help of the three independent components for the structure tensor

λ'_{xy} λ'_{xx} λ'_{yy}

the coherency

$$\Omega = [(\lambda'_{yy} - \lambda'_{xx})^2 + (2\lambda'_{xy})^2]/(\lambda'_{xx} + \lambda'_{yy})^2 \quad (5)$$

is defined. Its numerical range is from 0 for an isotropic greylevel structure to 1 for an ideal grid of parallel lines. The denominator of (5) involves information about local diameter of myotomes and the local binding state. The nominator of (5) involves information about local linearity of myotomes. Decreasing denominator is a sign for an increasing diameter of the myotomes or an increasing distance between the objects by loss of binding. The objects are classified due to their state of linear symmetry by the number of local coherency. All the occupied coherency states $K(\Omega)$ of the image objects were written due to the statistics of ideal gases (*Reif*, 1987):

$$K(\Omega) = a_1 \times \Omega^3 \times 1/[\exp(a_2 \times \Omega) - 1] \quad (6)$$

At the moment the detailed structure of the parameters a_1 and a_2 is unknown. They were fitted to the measured coherency data by minimising chi-square. The dependence of the pattern from physical or technological parameters as temperature, storage time and so on is contained in a_1 and a_2.

Results and discussion

Fish can be divided among other things according to their swimming behaviour in different groups: pelagic, demersal and flat fish. Of the fish investigated (Table 1) as an example for each group one species has been chosen to demonstrate the evaluation procedure. In Fig. 1–3 the greylevel images of cod, herring and Greenland halibut are shown. From this figures, after having been transformed into vector images by means of equation 1, the distribution of coherency has been measured by applying the equations 3 and 5 (Fig. 4–6). To check the physical model the measured values were compared with the theoretical model (equation 6). The results of this comparison are shown in Fig. 7–9, where the dotted line represents the measured coherency, and the solid one represents the theoretical values. The fitted parameters a_1 and a_2 for each of the fish species investigated are listed in Table 2.

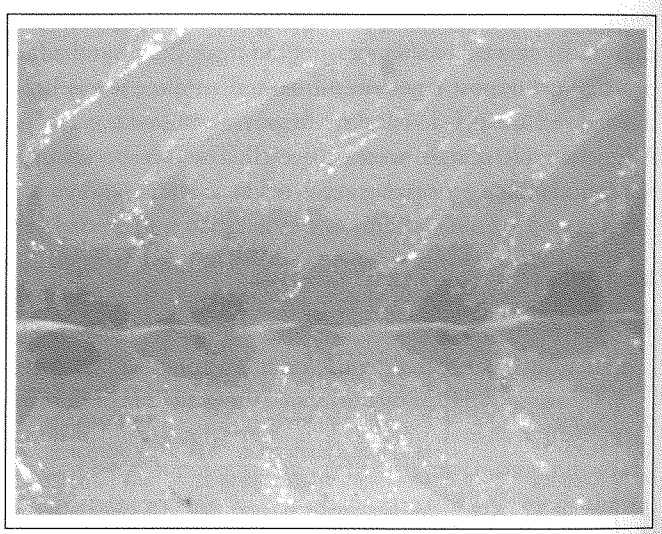

Fig. 1 Greylevel image of cod fillet

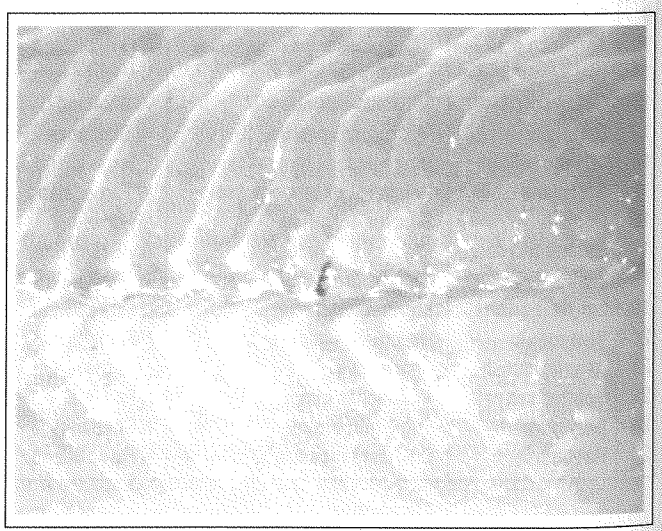

Fig. 2 Greylevel image of herring fillet

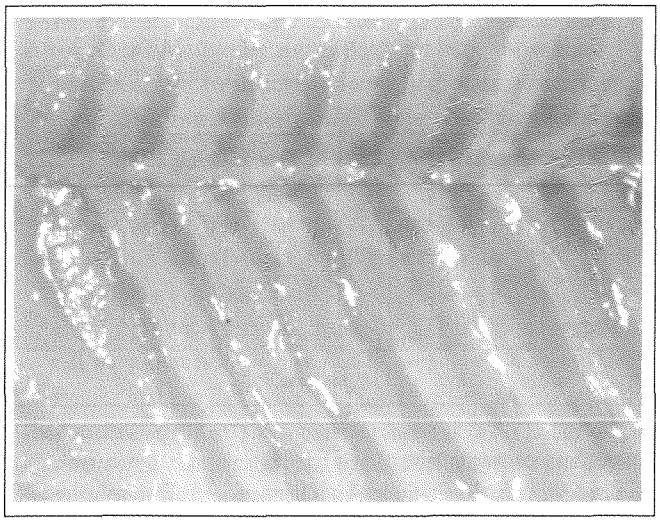

Fig. 3 Greylevel image of Greenland halibut fillet

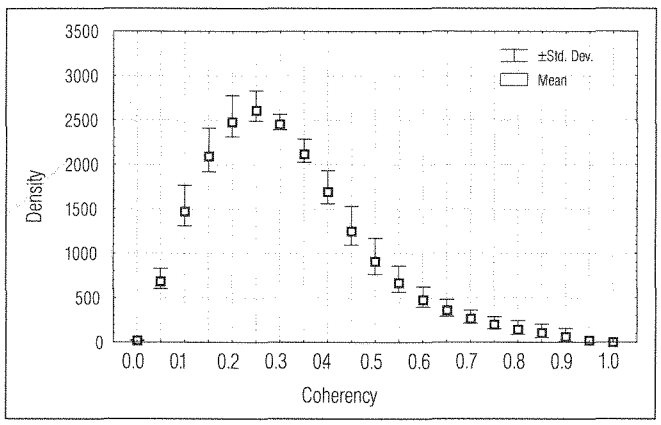

Fig. 4 Dependency of the distribution of coherency of cod fillet

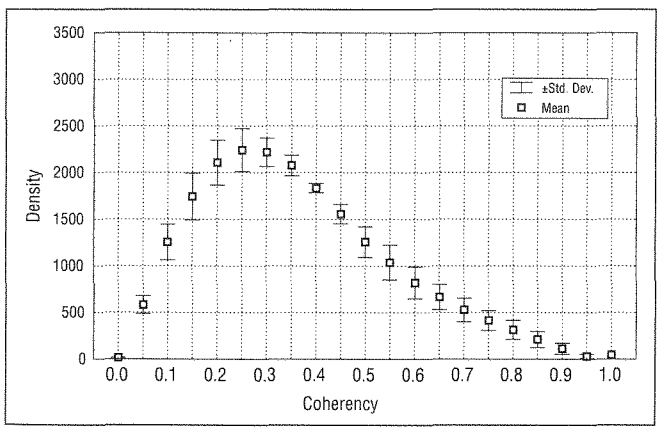

Fig. 5 Dependency of the distribution of coherency of herring fillet

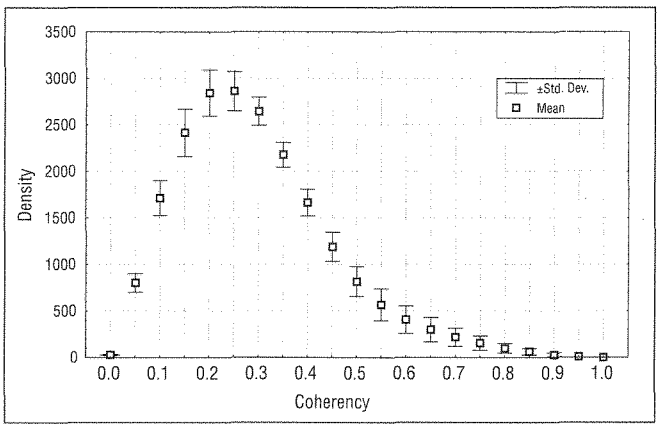

Fig. 6 Dependency of the distribution of coherency of Greenland halibut fillet

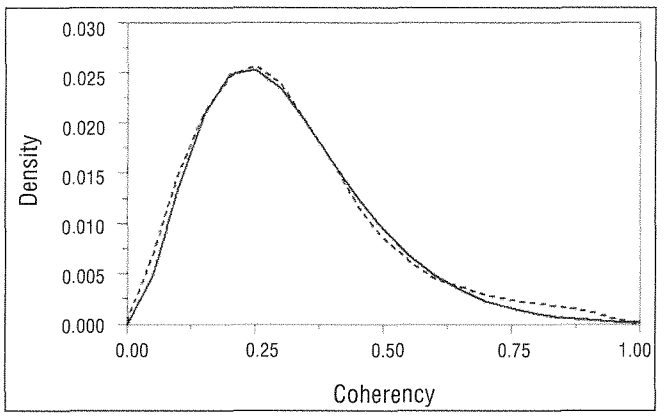

Fig. 7 Comparison of measured (dotted line) and according to equation (6) theoretically adapted (solid line) distribution of coherency of cod fillet

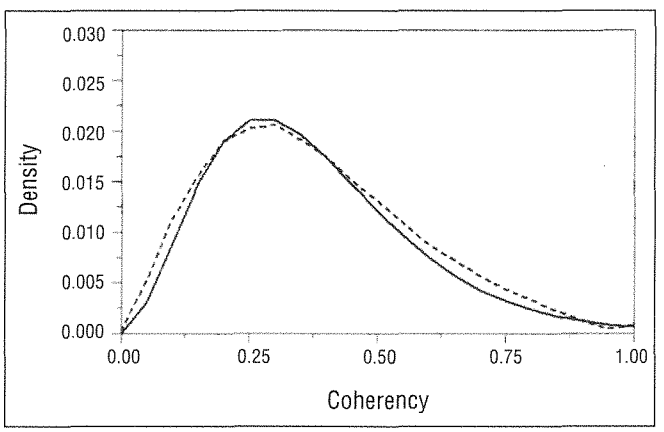

Fig. 8 Comparison of measured (dotted line) and according to equation (6) theoretically adapted (solid line) distribution of coherency of herring fillet

The parameters (Table 2) allow the separation of fish species in almost all cases except for the species Atlantic catfish and Spotted sea cat. They both are relatives and therefore not to differentiate by this processing. The grouping of the species according to pelagic and demersal is easily possible using both parameters a_1 and a_2 (Table 2). It seems impossible to differentiate flat fish species from the other ones due to broad range of values for flat fish. In addition to group flat fish successfully, further steps in another scale are necessary. This fact is underlined by Fig. 10 which demonstrates the different groups of fish species (demersal; 1–5, pelagic; 6–8 and flat fish; 9–11) by means of the product $a_1 \times a_2$. The numbers used in Fig. 10 characterise the fish species in Table 1.

Preliminary investigations were performed on the time dependency of coherence. On account of these investigations fillets processed from freshly-caught saithe were compared with fillets after passing the rigor stored in ice for 72 hours. Furthermore, saithe fillets which had been frozen after ice

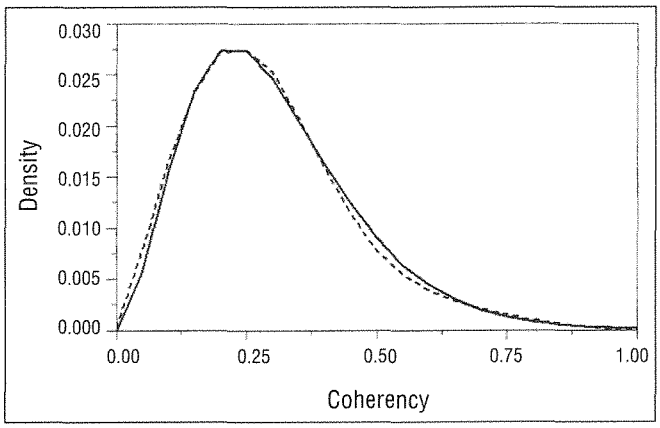

Fig. 9 Comparison of measured (dotted line) and according to equation (6) theoretically adapted (solid line) distribution of coherency of Greenland halibut fillet

Tab. 2 Parameters of the distribution of coherency

Species	a1	a2
Cod	30.05	11.90
Saithe	23.35	11.25
Hake	29.68	11.75
Haddock	33.32	12.27
Whiting	36.59	12.38
Herring	18.42	10.58
Mackerel	16.78	10.14
Horse mackerel	23.14	11.06
Plaice	27.01	11.56
American plaice	32.04	12.00
Dab	41.61	12.73
Ocean perch	33.92	12.16
Grenadier	27.69	11.63
Atlantic halibut	35.95	12.37
Greenland halibut	38.97	12.60
Dogfish	15.00	9.92
Greater forkbeard	29.94	11.91
Tusk	33.85	12.17
Ling	31.99	11.89
Blue mouth	33.51	12.09
Atlantic catfish	37.42	12.51
Spotted sea cat	37.87	12.57
Grey gurnard	27.61	11.53
Rabbit fish	15.78	10.11

storage of 72 hours and had been thawed after 10 days of frozen storage were evaluated. Fig. 11 demonstrates that passing the rigor provokes substantial changes of the parameters a_1, whereas freeze-thaw cycling does not seem to be connected with significant changes of both parameters a_1 and a_2. This could be seen as a reference of the preservation effect of the freezing procedure. This stated view is supported by Fig. 12 and Table 3. The peak maximum increased and shifted simultaneously to lower coherency for the sample after having passed the rigor. Therefore, it can be concluded that increasing storage time is connected with a loss of symmetry.

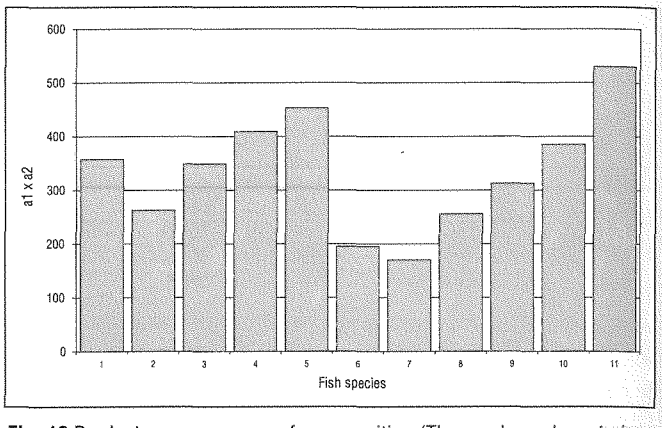

Fig. 10 Product $a_1 \times a_2$ as means for recognition (The numbers characterise fish species according to Table 1)

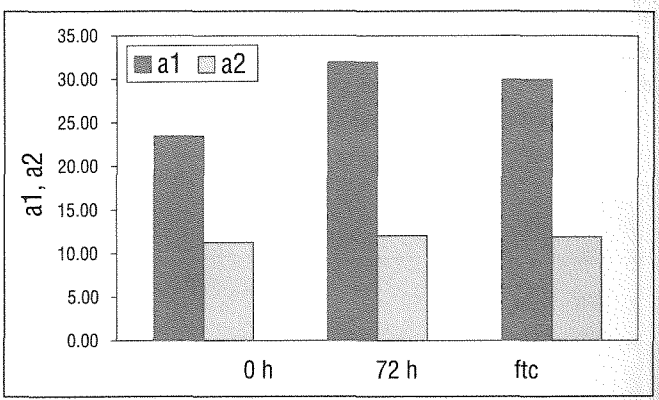

Fig. 11 Parameters a_1 and a_2 of saithe fillet as affected by rigor state and freeze/thaw cycle (ftc)

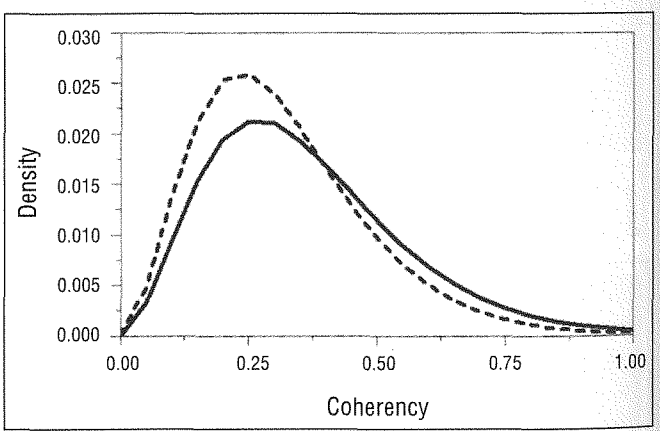

Fig. 12 Comparison of theoretically adapted distributions of coherency before rigor (solid line) and after having passed the rigor (dotted line) of saithe fillet

Table 3. Parameters of the distribution of coherency for saithe as affected by rigor state and freeze-thaw cycle

a1	a2	Storage time
23.50	11.25	2 h
31.99	12.05	72 h
29.95	11.89	Freeze/thaw cycle

Conclusions

Altogether the investigations detailed here show that

- it is possible to differentiate fish species by surface pattern of skinned fillet using a low cost hardware system and software tools based on effective numerical algorithms,
- the local symmetry of surface pattern of fish fillets derived from greylevel images contains information on the fish species investigated,
- local symmetry is influenced by physical and technological parameters.

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Rapid Ecologically Acceptable Method for Wheat Protein Content Determination – Comparison of Methods

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Summary

To display features of the rapid and simple automatic Dumas method for nitrogen determination in wheat flour the method was compared with the standard Kjeldahl method as a referential one.

The method is based on full incineration of sample and on total nitrogen determination in relation to the thermal conductivity of the nitrogen-helium mixture. Method testing proceeded by comparing the level of nitrogen in wheat flour samples determined by both methods. Data analysis of the protein content of the samples as determined by these two methods showed a significant positive correlation (r = 0.975). An assessment of the two methods' precision revealed that standard errors of the averages of parallel determinations were not essentially different, i. e., the results yielded by Dumas' method and standard Kjeldahl's method were the same. This rapid, simple and readily performed method permits doing many tests daily, using up a small amount of the sample (0.1–1g) and dispensing with the use of noxious chemicals. It can thus be recommended as a very simple method to use and constituting an ecologically acceptable replacement for the standard Kjeldahl's method.

Zusammenfassung

Um die Charakteristiken der einfachen und schnellen Dumas-Methode für die Stickstoff-Bestimmung in Weizenmehl zu zeigen, wurde diese Methode mit dem Standard-Kjeldahl-Verfahren verglichen. Die Dumas-Methode basiert auf der totalen Veraschung der Probe und anschließender Bestimmung des Gesamt-Stickstoffs in Bezug auf die Wärmekonduktivität der Stickstoff-Helium-Mischung. Beide Methoden wurden miteinander verglichen. Die vergleichende Daten-Analyse der Bestimmung des Proteingehaltes der Probe zeigte eine eindeutige positive Korrelation (r = 0,975). Auch die Standard-Abweichungen beider Methoden waren vergleichbar. Somit ermöglicht die Dumas-Methode die Durchführung einer Vielzahl von täglichen Tests bei minimalem Probenverbrauch und der Verringerung des Einsatzes von schädlichen Chemikalien (0,1–1g).

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