Production of organic milk of high quality considering the future demands for use of organically produced feed and natural vitamins

Acronym: ORMILQ

Date: 26th November 2001

Summary in Danish:
Fremtidige regler for økologisk produktion af mælk betinger, at al foder er økologisk produceret og at koen kun må forsynes med naturlige vitaminer. Dette indebærer så drastiske ændringer i fodringen, at det må formodes at få indflydelse på mælkens antioxidative kapacitet og dermed holdbarhed. Projektet sigter mod at belyse hvilke konsekvenser nye regler for økologisk fodring og anvendelse af naturlige vitaminer og antioxidanter til køer, der indgår i økologisk mælkeproduktion, vil have for mælkens antioxidative kapacitet. Nye forsøg viser, at urinsyre i mælk er en vigtig antioxidant af betydning for mælkens oxidative stabilitet. Under projektet ønskes det således, at øge koens forsyning af selen og dannelse af endogene antioxidanter (urinsyre og glutathionperoxidase) for derigennem at producere oxidativt stabilt mælk og mejeriprodukter.

1. Summary

Future regulations for organic production of milk stipulate that all feed must be organically produced, and that the cow can only be fed natural vitamins and antioxidants.This leads to feeding changes of such a magnitude that it must be presumed to influence the antioxidative capacity and thus the shelf-life of the milk. The project aims at elucidating the nature of the consequences that these new regulations for organic feeding and use of natural vitamins and antioxidants for cows in organic milk production will have on the antioxidative capacity of the milk. New studies show that uric acid in milk is an important antioxidant of significance for the oxidative stability of milk. During the project, it is the aim to increase the supply of selenium and the development of endogeneous antioxidants (uric acid and glutathione peroxidase) in order to produce oxidatively stable milk and dairy products.

2. Research group

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3. Introduction and state of the art

Today organic milk production imply that all the feed for the cows is produced under organic conditions, which results in a high degree of self-sufficiency. It is presumed that the future feeding will contain a higher level of roughage and clover grass in the basic diet. The fat supply for the cow will thus be reduced significantly, and polyunsaturated fatty acids from grazing and silage will form the major part of the fat. The fatty acid composition in milk is the decisive factor for the oxidative stability of the milk and the dairy products, and this change will probably result in a larger variation in the milk quality and an increased oxidation as a consequence of an increased intake of polyunsaturated fatty acids from grazing. A report on Swedish milk has thus shown that organic milk displays "oxidized taste" three times as frequently as conventionally produced milk (personal communication). The oxidative stability of milk can be increased by an elevated content of antioxidants in the milk, which means that the combination of dietary addition of antioxidants and the ability of the cow to form antioxidants is decisive for obtaining an optimal milk quality.

Dairy products are very sensitive to light and oxidative deterioration of dairy products are often initiated by exposure to light. Light induced oxidation results in off-flavours, discolorations and decrease in nutritive value and formation of potentially toxic compounds. In dairy product riboflavin, a B-vitamin, is acting as a photosensitizier absorbing visible light and initiating free radical processes in proteins and lipids. Riboflavin induced protein oxidation thus result in a characteristic "burnt leather" off-flavour, while the subsequent lipid oxidation leads to a "card board" off-flavour. Riboflavin is partly degraded during the processes leading to loss of the important vitamins. It is difficult to avoid exposure of products to light during processing, storage and retail display and even short-term light exposure may induce processes in the product during subsequent storage.

Vitamin E is very important for the antioxidative stability of the milk, and the concentration of this antioxidant must be very high, especially if the milk has a high content of unsaturated fatty acids (St-Laurent et al., 1990; Nicholson et al., 1991). Vitamin E and β-carotene are potential protectors of light induced processes since these compounds quench activated oxygen (singlet oxygen) and riboflavin is the excited, reactive state. The interaction of these photoprotectors with other antioxidants like uric acid and selenium proteins is not known.

According to "Vejledning om økologisk jordbrug, august 2000" [Guide for organic farming, August 2000] it applies that synthetically produced vitamins cannot be used for dietary addition of vitamin E in organic milk production. This implies that during the winter season natural vitamins must be added (Knudsen et al., 2001). Such natural vitamins could be e.g. sunflower isolates, however the cost of these causes the production to be unprofitable.

It must be assumed that the demand for natural vitamins and the change to use only organically produced feed will result in a depreciation of the milk quality, if the feeding strategy is not based on strategic feeding in preparation for optimal milk quality as regards content of antioxidants.

Four aspects in relation to an increased antioxidative capacity of milk should thus be considered:

1. Several studies indicate that the natural isomer of vitamin E present in the crop has a larger antioxidative potential than the synthetically produced vitamin E (Jones, 2000). However, these circumstances are poorly elucidated in relation to the shelf-life of milk.
2. Selenium is an important mineral, which form part of the antioxidative enzyme gluthatione peroxidase (GPX), and the amount of selenium is directly related to the concentration of GPX in the milk (Mahan & Parett, 1996). Selenium can be organically bound in the feed or added as inorganic selenium via mineral mixtures added to the feed. Especially the organically bound selenium tends to be significant for GPX in milk. GPX is heat-stable (Lindmark-Mansson et al, 2001) and are able to reduce hydrogen peroxide and lipid hydroperoxides . Therefore this enzyme is assumed to be of notable importance for the shelf-life of the milk. Selenium is present in the crops, and a number of herbs are able to accumulate selenium in high concentrations. Preliminary studies show that sowing of chicory in grass fields increases the selenium content in the crops (Pers Comm.).
3. A change in the feeding strategy with a higher proportion of grazing, silage and green pills in the feed will increase the content of carotenoids in the milk (Barrefors & Everitt, 1995) . Carotenoids are known as being antioxidants in milk (Lindmark-Månnsson & Åkesson, 2000) and have proven to be especially effective at quenching singlet oxygen in connection with light-initiated oxidation in milk (Tsung et al., 2000). When trying to obtain a high content of carotenoids in the feed, the oxidative stability of the milk may be improved
4. New results show that uric acid in milk is an effective antioxidant (Østdal et al., 2000) and possibly as effective as vitamin E. Small-scale studies have thus shown that uric acid in milk is an especially good antioxidant in relation with light-induced oxidation, and that milk with a high uric acid content is very stable despite the lower content of α-tocopherol (Østdal et al., 2001). The content of uric acid in the milk can be increased by approximately 30% via an increase in the microbial metabolism in the rumen through alteration of the feeding strategies (Nielsen et al., 2001) by administering less fat and more fermentable feed.

It can thus be assumed that an increase in the selenium content in the feed and a change in feeding strategy in order to increase the uric acid content of the milk may compensate for the changed feeding practice in connection with the introduction of 100% organic production and thus ensure a high milk quality.

4. Objectives and expected achievements

Objective

To elucidate the effect of introducing new rules for organic feeding and use of natural vitamins and antioxidants on the antioxidative capacity of the milk from cows producing milk under organic conditions. Furthermore to increase the selenium supply and the formation of endogenous antioxidants (uric acid and glutathione peroxidase) of the cow in order to produce oxidatively stable milk and dairy products.

The aim consists of the below intermediate aims:

- to study the variation in content of pro- and antioxidants in organic milk from a number of herds in relation to regional variation, feeding and season
- to study whether the natural isomer of vitamin E is a more effective antioxidant than the synthetic isomer of vitamin E
- to study whether the natural carotenoid content in milk has an antioxidative effect
- to study whether cheese exposed to light shows improved antioxidative characteristics if it is based on milk with a high uric acid content
- to make guidelines on how to improve the oxidative stability of the organic milk through feeding

The project aims at investigating the possibility to create processed dairy products (cheese) with an oxidative stability up to the same standards as conventionally produced dairy products. The project will introduce the possibility of using endogenously formed antioxidants (uric acid and glutathione peroxidase) and natural vitamin E to improve shelf-life of organic dairy products. The project is holistic and comprises the chain from stable to table. It involves inter-institutional cooperation and is based on expertise at both KVL and at DJF.

5. Description of workpackages including methods

Table 1: Workpackage list

WP No	WP title	Responsible participant	Budget	Start	End	Deliverable, No
1	Antioxidative capacity of raw milk	DJF	3,026,400	010202	311204	D1-D11
2	Cheese production and oxidative stability of cheeses with high level of uric acid and selenium	KVL	624,000	010104	311204	D5,D8,D12
Total			3,650,400			

Table 2: Description of workpackages

WP1: Antioxidative capacity of raw milk

Workpackage number:	**1**
Start date or starting event:	**010202**
Responsible person:	**Jacob Holm Nielsen**
Contributing persons:	**Henrik Østdal**
Person-months:	**Researcher 30; Technician 36**

Objectives:

- to study the variation in content of pro- and antioxidants in organic milk from a number of herds in relation to regional variation, feeding and season
- to study whether the natural isomer of vitamin E is a more effective antioxidant than the synthetic isomer of vitamin E
- to study whether the natural carotenoid content in milk has an antioxidative effect

Description of work:

Task 1:

Characterization of milk from organic herds

Yield, protein percentage, fat content, fatty acid composition as well as content of isomers of tocopherols, carotenoid, copper, selenium, GPX and uric acid are determined in a number of milk samples from organic herds (15 herds representative of regional variation (Studielandbrug and selcted herds), milk from each herd are analysed 5 times during the season). The samples are taken through the whole season, and thus they represent all the different kinds of feeding and the season variations. In addition, milk is sampled from individuals (milk from 6 cows analysed 5 times during the season) in order to elucidate the significance of lactation phase.

Task 2:

Variation in the oxidative stability of milk

Selected milk samples representing a broad variation regarding feeding composition and lactation phase are stored for 3 days at 4^{o}C (10 samples from different herds) . The oxidation is followed through measurements of lipid hydroperoxides, flavour components using high-vacuum distillation, electronic nose, protein oxidation and electron spin resonance (ESR) spectroscopy.

Task 3:

Feeding experiments with natural vitamin E

In order to investigate whether natural isomers of vitamin E have a larger antioxidative potential than the equivalent synthetic vitamin E, feeding experiments with adequate amounts of synthetic and natural vitamin E are accomplished (2 x3 cows, latin square, the experiment is repeated twice). The shelf-life and the flavour of milk are analysed using ESR-spectroscopy, measurement of lipid hydroperoxides and flavour components at high-vacuum distillation besides accelerated models for estimating of the shelf-life of the milk.

Task 4:

Model studies with vitamin E incorporated in the milk fat globule membrane

Studies isolating the fat globule membrane containing vitamin E are carried out. Subsequently their oxidative stability is studied in model systems. These studies include oxidative changes in membranes, assays to estitimate antioxidative capacity and differential scanning calorimetry to describe changes in phase transitions in the fat globule membrane of milk.

Deliverables:
D1-D5 Report for the Danish Dairy Board
D6 Final report for FØJO and the Danish Dairy Board
D7 Paper for Mælkeritidende
D8 Paper for Mælkeritidende
D9 The shelf life of organic milk in relation to feeding (paper)
D10 The antioxidative capacity of natural vitamin E in milk (paper)
D11 Mechanistic study of vitamin E in MFGM (paper)

Milestones:

WP1:
M1: Characterization of milk from organic herds finished
M2: Variation in the oxidative stability of milk
M3: Feeding experiments with natural vitamin E finished
M4: Model experiments with vitamin E incorporated in the fat globule Membrane of milk
M5: Light induced processes in cheese is described in relation to the level of natural antioxidants (Analysis of flavour components by high vacuum distillation are performed at DJF)

WP2: Cheese production and oxidative stability of cheeses with high level of uric acid and selenium

Workpackage number:	**2**
Start date or starting event:	**010104**
Responsible person:	**Professor Leif Skibsted**
Contributing persons:	
Person-months:	**Researcher 12**

Objectives:

- to study whether cheese exposed to light shows improved antioxidative characteristics if it is based on milk with a high uric acid content

Description of work:
Cheese produced from milk of high content of uric acid and selenium
Task 5
Milk with high content of uric acid and selenium is produced via strategic feeding. This milk is used to produce acidulated cheese (to avoid the effect of starter cultures), which is subsequently stored

under light exposure in order to study the antioxidative effect of uric acid and selenium.

At Food Chemistry, methods have been established for controlled exposure of food products and quantification of light induced processes. These methods include analyses of model systems, where the interaction between light absorbing compounds and oxidation substrates can be investigated. Studies of light effects in real products can be studied using storage facilities with controlled illumination followed by analyses of the products.

The resistance of a fresh cheese as an example of a dairy product made from organic milk to light induce oxidation is described in relation to the content of natural antioxidants. This quantitative information will aids in defining the required level of natural antioxidants in organic milk in order to give product with flavour stability.

Deliverables:
D5 Report for the Danish Dairy Board
D8 Paper for Mælkeritidende
D12 Influence of urate and selenium on light induced oxidative changes in cheese

Milestones:
M5: Light induced processes in cheese is described in relation to the level of natural antioxidants

6. Implementation and time schedule

Table 3: Deliverables list

Deliver-able, No	Deliverable title	Delivery date	Meeting	Nature
D1	Report for the Danish Dairy Board	**10/2002**		**Report**
D2	Report for the Danish Dairy Board	**04/2003**		**Report**
D3	Report for the Danish Dairy Board	**10/2003**		**Report**
D4	Report for the Danish Dairy Board	**04/2004**		**Report**
D5	Report for the Danish Dairy Board	**10/2004**		**Report**
D6	Final report for FØJO and the Danish Dairy Board	**12/2004**		**Report**
D7	Paper for Mælkeritidende	**05/2002**		**Paper**
D8	Paper for Mælkeritidende	**10/2004**		**Paper**
D9	The shelf life of organic milk in relation to feeding (paper)	**8/2002**		**Int. paper**
D10	The antioxidative capacity of natural vitamin E in milk (paper)	**6/2004**		**Int. paper**
D11	Mechanistic study of vitamin E in MFGM (paper)	**8/2004**		**Int. paper**
D12	Light induced processes in cheese is described in relation to the level of natural antioxidants	**12/2004**		**Int. paper**

Table 4: Timetable

TI-TLE		2002*				2003*				2004*				2004*				2005*			
Tasks	**Co-ordination Quarter**	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	**WP1:**						5														
2							5														
3										3											
4										3											
M1							5														
M2							5														
M3										3											
M4										3											
M5													12								
	WP2:																				
5													12								
M5													12								

* If convenient, indicate the actual month (can be dome by numbers: January is 1 etc.)

7. Collaborative partners

DJF is collaboratic with Swedish Milk in relation to quality of organic milk

8. Budget

Applied at FØJO and the Danish Dairy Board, see appendix

Institution 1, DJF	**2002**	**2003**	**2004**
Months (scientific)	10	10	10
Months (technical)	12	12	12
Salary (scientific)	350,000	360,000	371,000
Salary (technical)	264,000	273,000	279,000
Operation – equipment	300,000*		
Operation – other	80,000	105,000	140,000
Overhead	198,800	147,600	158,000
Total	1,192,800	885,600	948,000

HPLC for

Institution 2, KVL	**2004**
Months (scientific)	12
Months (technical)	
Salary (scientific)	400,000
Salary (technical)	
Operation – equipment	
Operation – other	120,000
Overhead	104,000
Total	624,000

Applied at FØJO: 1,998,000 Dkr. which constitutes 54.7% of the total amount

9. References

Barrefors P. & Everitt B. (1995) Milk in nutrition effects of production and processing factors 135-148

Jones M (2000) International Food Ingredients **6** 34-35

Knudsen B S, Hermansen J E, Jensen S K, Kristensen T & Nielsen M O (2001) DJF Rapport Nr. 27

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Lindmark- Månsson H., Jun-Chen, Paulsson M., Alden G., Ren B., Ladenstein R. Åkesson B. (2001) *International Dairy Journal* **11** 71-81

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Nicholson J. W. G., St-Laurent A. M., Mc Queen R. E. & Charmley E. (1991) ***Canadian Journal of Animal Science*** **71** 135-143

Nielsen J H, Østdal H & Andersen H J (2001a) Chapter 9 in *Free Radicals in Foods: Chemistry, Nutrition, and Health Effects. American Chemical Society Symposium Series* No. 807 (printed).

Nielsen J. H., Hald G., Kjeldsen L., Andersen H. J. & Østdal H. (2001) *Journal of Agricultural and Food Chemistry* **49** 2998-3003

Pers. Comm. (Swedisk milk)

St-Laurent A. M., Hidiroglou M., Snoddon M. & Nicholson J. W. G. ***(1990) Canadian Journal of Animal Science*** **70** 561-570

Tsung-Lin-Li, King J. M. & Min D. B. (2000) *Journal of Food Bi*ochemistry **24** 477-492

Østdal H, Andersen H J , & Nielsen J H (2000) *Journal of Agricultural and Food Chemistry.* **48**, 5588-5592

Østdal H, Andersen H J , & Nielsen J H (2001)

Appendix: 1

Continuity and Building of Knowledge

The Danish Institute of Agricultural Sciences is a part of the Danish Ministry of Food, Agriculture and Fisheries and has approximately 1100 employes. The institute coveres research from gene to fork and has fascilities for production of specific types af feed and our own production herd making it possible to study effects of feeding on milk qulaity.

Department of Animal Product Quality has app. 50 employes and conducts research in the areas of oxidation and flavour, protein characterization, muscle biology and physical changes in animal products and foods. The department has its own pilot plant with a pasteurization line and pumping equipment as well as advanced analytical equipment including GC/MS, ESR, DSC and chromatographic equipment for analysis of oxidation products, flavour components and antioxidants. The scientific staff working with oxidation and flavour in animal products and foods includes five senior researchers, two researchers, two PhD-students and one master student.

Jacob Holm Nielsen, Oxidation and Flavour group leader, has conducted research in relation to oxidative changes in foods and has during the last five years coordinated several research projects concerning milk quality.

Henrik Østdal, senior researcher in Oxidation and Flavour group, has conducted research in relation to oxidation in biological systems with special emphasis on protein oxidation and pro-oxidative effects of heme proteins.

Today the Department of Animal Product Quality (ANF) at DJF performs the major part of the national efforts regarding milk quality research in relation to the oxidative stability and flavour of the raw material. ANF has much experience with analysis of vitamins, fatty acid composition, measuring enzyme activities, measuring oxidative changes and flavour profiling in milk. Through recent years, ANF has worked in cooperation with organic dairies, the Directorate for Food, Fisheries and Agri Business, KVL and MFF regarding the quality of organic milk. The cooperation has i.a. been based on the projects “Aroma and flavour of organic milk”, “Organic milk quality – Improvement through gentle storage on-herd”, “Early events at oxidation in milk: Improvement of shelf-life of dairy products especially regarding organic milk production” and “Flavour in milk - effect of feeding, treatment and storage of raw milk”. The present project will be based on experiences and continue the work achieved in these projects.

The Royal Veterinary and Agricultural University (KVL) has approximately 3500 students and 350 graduate students. Department of Dairy and Food Science (MLI) is one of the largest departments at KVL and is combining basic food related research with applied science in relation to collaborative projects with the food industry. Food Chemistry is one of seven scientific units at MLI with a total of 35 employees and graduate students. KVL and Technical University of Denmark (DTU) are both partners in LMC Center for Advanced Food Studies, which coordinate academic training in food science and technology and food research in Denmark. LMC has now obtained status of Major Research Installation (MRI) by EU, and Food Chemistry is one of nine scientific disciplines in this only MRI in food science establish by EU.

The Food Chemistry group has established 'state-of-the-art' facilities for the study of oxidative processes in food and on mechanism behind the protective capacities of antioxidants. This is for instance linked to the research in the Human Nutrition group on the health promoting effects of foods with high content of antioxidants. The facilities are unique in that they allow all stages of the oxidative processes to be studied on relevant time scales and the following of the different effects on the food system. In this respect studies has been focused on the kinetics of oxidative changes and mechanisms behind antioxidants with special emphasis on optimisation of natural antioxidants and the effect of synergism. The group has a comprehensive knowledge about lipid oxidation based on an extensive selection of chemical analyses for characterisation of products and for evaluation of quality in relations with sensory profiling. Methods for detection of early events in the oxidation process concerning evaluation of oxidative stability of food products, has been established. For a number of products like milk powder and dried chicken meat direct measurements of radicals with ESR-spectroscopy has been shown to correlate with flavour development due to oxidation. Recently a method has been developed, to measure the early events of the oxidative processes in milk in connection with the project "Early events at oxidation in milk: Improvement of shelf-life of dairy products especially regarding organic milk production". Furthermore, Food Chemistry has a general experience regarding studies of the oxidative stability of dairy products, including cheese, cheese spreads and butter. In this way experimental methods for quantitative estimation of light exposure has been developed.

Leif Skibsted has originally a background in research in thermodynamics, kinetics of photochemistry of transition model compounds. Later he specialised in food chemistry with special emphasis on the kinetics of oxidative changes in food and the role of mechanism of antioxidants. He has been research director for KVL Center for Food Research (1991-1994) and coordinated a large EU-project on dietary treatment and oxidative stability of muscle and meat products: nutritive value, sensory quality and safety. Current research action is focused on mechanism behind antioxidant synergism and methods for prediction of oxidative stability of food, based on early measurements.

Detailed Budget:

FØJO	**2002**	**2003**	**2004**	**2002-2004**
Salary (scient.)	300	260	450	1010
Salary (tech.)	120	130	140	390
Equipment	-	-	-	
Feeding exp.	-	25	60	85
Operation	40	40	100	180
Overhead	92	91	104	333
Total	552	546	624	1998

Danish Dairy Board	**2002**	**2003**	**2004**	**2002-2004**
Salary (scient.)	50	100	121	471
Salary (tech.)	144	143	139	426
Investering	300	-	-	300
Feeding exp.	-	-	-	-
Operation	40	40	100	180
Overhead	106.8	56.6	112	275.4
Total	640.8	339.6	672	1652.4

All amounts in kkr.

Curriculum vitae

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Education

Royal Danish School of Pharmacy, Copenhagen — Cand.pharm. (1972), Ph.D (1976)

Research and/or professional experience

Assistant professor, Chemistry Dept., Royal Veterinary and Agricultural University	1974-76
Associate professor, Chemistry Dept., Royal Veterinary and Agricultural University	1976-88
Research associate, University of California at Santa Barbara	1978-79
Docent, Chemistry Dept., Royal Veterinary and Agricultural University	1988-92
Research Director, KVL Centre for Food Research, Royal Veterinary and Agricultural University	1991-94
Chairman of board, Institute for Dairy Research, Royal Veterinary and Agricultural University	1991-95
Professor of Food Chemistry/ Physics, Dept. of Dairy and Food Science, Royal Veterinary and Agricultural University	1992-
Technical consultant for "Den Store Danske Encyklopædi" (The Danish Encyclopedia)	1992-
Research Area Manager, Centre for Advanced Food Studies, Royal Veterinary and Agricultural University and Technical University of Denmark	1995-97
Co-ordinator, EU-project, Dietary Treatment and Oxidative Stability of Muscle and Meat Products: Nutritive value, Sensory Quality and Safety, AIR2-CT94-1577	1995-97

Research activities

Photochemistry, photophysics, reaction kinetics and thermodynamics of transition metal compounds. Food chemistry and food physics with special emphasis on kinetics of oxidative changes in foods, including light induced processes and transition metal catalyzed processes. Spectroscopic techniques for the study of properties and reactions of biomolecules, including electron spin resonance spectroscopy, time resolved fluorescence, stopped-flow spectroscopy and nanosecond laser-flash transient absorption spectroscopy. Calorimetric characterization of phase transitions in foods. High pressure methods in food processing. More than 200 scientific papers in refereed journals.

Awards

H.C. Ørsted Medal, the Royal Danish School of Pharmacy	1972
Ole Rømer Award, Danish Ministry of Education	1981
Ellen and Niels Bjerrum's Award and Gold Meda	1986
Ulrich and Marie Brinch's Award	1993
The Food Science Award, Danish Society of Food Science and Technology	1994
The Carlsberg Research Award in Agricultural Science	1996
Students Award as Teacher of the Year (Den Gyldne Tyr, KVL)	2001

Memberships

Danish Academy of Technical Sciences (ATV), elected member	1997-
Editorial Board, European Food Research and Technology	1997-

Recent references

1. Dorthe Kristensen, Eva Hansen, Allan Arndal, Rikke Appelgren Trinderup & Leif H. Skibsted: Influence of light and temperature on the colour and oxidative stability of processed cheese. Int. Dairy Journal, 11, 2001, 837-843

2. Dorthe Kristensen,Morten Boesen, Ulrik Lund Jacobsen, Lars Månsson, Lars Erichsen & Leif H. Skibsted: Oxidative and colour stability of salted sour cream dairy spread compared to salted sweet cream dairy spread. Milchwissenschaft, 55, 2000, 504-507

3. Dorthe Kristensen, Vibeke Orlien, Grith Mortensen, Per Brockhoff & Leif H. Skibsted: Light induced oxidation in sliced havarti cheese packaged in modified atmosphere. Int. Dairy Journal, 10, 2000, 95-103

4. Eva Hansen & Leif H. Skibsted: Light induced oxidative changes in a model dairy spread. Wavelength dependence of quantum yields. J. Agric. Food Chem., 48, 2000, 3090-3094

5. Dorthe Kristensen & Leif H. Skibsted: Comparison of three methods based on Electron Spin Resonance Spectrometry for evaluation of oxidative stability of processed cheese. J. Agric. Food Chem., 47, 1999, 3099-3104

CURRICULUM VITAE

Jacob Holm Nielsen (born in 1958) Head of research unit, MSc, PhD
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Education:
M. Sc. in biologi (1992)
Ph. D. in food chemistry (1995) "Cholesterol oxidation in dairy products"

Employments:

May 1992-June 1995	**Ph.D-student, Centre for Food Research**
June 1995-June 1996	Research Assistent professor, Mejeri og Levnedsmiddel Instituttet, KVL
June 1996-December 1998	Senior scientist, Department of Animal Product Quality, DIAS
December 1998-	Head of research unit, Department of Animal Product Quality, DIAS

Other activities:
Censor at KVL in food chemistry
Project mangement:
Flavour and taste of organic milk
Organic milk quality-Improvement through gentle storage
Improvement of shelf life and quality of dried egg powder
Drip loss as influenced by calcium in pork
Milk quality as influenced by somatic cells in milk
Sensory and technological quality of milk as affected by automatic milkin
Flavour in milk as influenced by feeding, mechanical stress and storage of the raw milk
Early events for oxidation of milk – significance for oxidative stability of organic milk and dairy products (Only for DIAS)

Recent references

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J. H. Nielsen, H. Østdal & H. J. Andersen (2001) The influence of ascorbic acid and uric acid on the oxidative stability of raw and pasteurized milk. *ACS Books: Radicals in Foods* (review, accepted)
J. H. Nielsen, G. Hald, L. Kjeldsen, H. J. Andersen & H. Østdal (2001) Oxidation of ascorbate in raw milk induced by enzymes and transition metals. ***Journal of Agricultural and Food Chemistry*** 49 **2998-3003**
L. WIKING, M.B. FRØST, L.B LARSEN, J.H. NIELSEN (2001) Effects of storage conditions on lipolysis, proteolysis and sensory attributes in high quality raw milk. ***Milch Wissenschaft*** **(accepted)**
I. H. Lambert, J. H. Nielsen & N. Ørtenblad (2001) Cellular model for introduction of drip loss in meat. *Journal of Agricultural and Food Chemistry* **49** *4876-4883*