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Original paper

Pea fibre as a source of natural antioxidants in frozen minced beef

Lipid oxidation and colour stability during retail display

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Erbsenrohfasern als natürliche Antioxidantien in gefrorenem, gehacktem Rindfleisch. Lipid-Oxidation und Farbstabilität während der Lagerung im Einzelhandel

Zusammenfassung. Die antioxidative Wirkung der Rohfasern aus gelben Felderbsen in Hackrindfleisch mit 1% Salzzusatz wurde mit der antioxidativen Wirkung von rehydratisiertem, texturisiertem Sojaprotein verglichen. Die Oxymyoglobin-Autoxidation in der Oberfläche des Produktes wurde mit der Tristimulus-Colorimetrie während einer sechswöchentlichen Gefrierlagerung (Plastiktuben, Durchmesser 8 cm, Produkttemperatur −18 °C in einem Kühlfach mit Leuchtstofflampen) beobachtet. Die Lipid-Oxidation in der Mitte bzw. Oberfläche des Produktes wurde durch die Bestimmung der mit Thiobarbitursäure reagierenden Substanzen (TBS-Wert) erfaßt. Die Lipid-Oxidation in der Produktmitte war in keinem der Produkte von Bedeutung, während der TBS-Wert in der Oberfläche des Vergleichproduktes anstieg, und zwar auf 33 mg Malonaldehyd/kg Produkt nach Beleuchtung und auf 26 mg/kg ohne Beleuchtung. Sowohl die Erbsenfasern als auch das Sojaprotein liefern einen wirksamen Schutz gegen diese Lipid-Oxidation in der Oberfläche; die antioxidative Wirkung der Erbsenfasern wurde zusätzlich bewiesen in einem wäßrigen Extrakt. Was die Pigment-Oxidation betrifft, so hatten die Erbsenfasern auch eine antioxidative Wirkung auf die Farbstabilität des gehackten Rindfleischproduktes, wenn auch das Sojaprotein einen viel wirksameren Schutz gegen die Oxymyoglobin-Autoxidation leistete.

Summary. The antioxidative effect of rehydrated fibre from yellow field pea in a minced beef product with 1% salt added has been compared to the antioxidative effect of rehydrated texturized soy protein. The oxymyoglobin autoxidation in the product surface was followed by tristimulus colorimetry during freezer storage (polyethylene tubes, diameter 8 cm, product temperature −18° C) for 6 weeks in a display cabinet illuminated by fluorescent tubes. Lipid oxidation in the product center and in the product surface was followed by a determination of thiobarbituric-acid-reactive substances (TBA). Lipid oxidation in the product center was hardly significant in any of the products, whereas the TBA value in the surface layer of an all-meat reference product rose to 33 mg malonaldehyde/kg product when exposed to light, and to 26 mg/kg when protected against light. Both pea fibre and soy protein yielded an efficient protection against this surface lipid oxidation, and the antioxidative effect of the pea fibre was further verified in a model system for an aqueous extract. As for the pigment oxidation, pea fibre also had an antioxidative effect resulting in a better colour stability of the minced beef product, although soy protein yielded an significantly better protection against oxymyoglobin autoxidation.

Introduction

Yellow pea fibre products have recently been introduced as an alternative to soy protein for use in different meat products. Yellow pea fibres are fibrous functional ingredients produced from ripe, yellow field peas. The most important property of the fibre products in relation to meat products is the excellent water-binding capacity. Beside this function, the pea fibre products also provide a better structure in meat products, and can be used as a fat-replacing agent [1]. The use of pea fibre in a variety of meat products, such as hamburger patties and other convenience foods, can accordingly also be recommended from a nutritional point of view.

Since pea fibre is produced from a domestic crop, it could be a useful replacement for soy protein which, in rehydrated form, is widely used in minced beef products in Denmark (replacing up to 50% of the meat in certain products). Soy protein and other oil seed protein derivatives have been shown to reduce lipid oxidation in several types of meat products [2–7] and in model systems [8–10],

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whereas conflicting reports on the effect of the proteins on meat colour and on the colour stability of meat products during storage have appeared [5, 11].

In a recent study, Grzeskowiak et al. [12] have shown that ground yellow pea also exhibits strong antioxidant properties towards lard and low-erucic-acid rapeseed oil, and that the antioxidant effectiveness is a variety-specific property. No studies have, however, appeared on the antioxidative effect of fibre products made from yellow peas. The interest in a future use of pea fibre in meat products, together with the lack of knowledge of the antioxidative effect of such fibre products when combined with meat, have provided a strong incentive to study the effect of a yellow pea fibre product on the rate of lipid oxidation in a model meat system and in frozen, minced beef.

Accordingly, the antioxidant effectiveness of the yellow pea fibre product was compared with the antioxidant properties of a texturized soy protein product normally used in minced beef products. Moreover, we have compared the colour stability of frozen, minced beef during retail display of a product with added soy protein and a product with added pea fibre in order to clarify whether pigment oxidation and colour stability are influenced in these meat products.

Materials and methods

Materials

Conventionally cold deboned beef (beef trimming; pH 5.8) was used for the three productions. Semimembranous was used for the model experiments. NaCl of food grade (Slagteriernes Fællesindkøbsforening, Hvidovre, Denmark), texturized soy protein (Textratein 4N50, Slagteriernes Fællesindkøbsforening, Hvidovre, Denmark), and a pea fibre product (Nutrio P-Fibre 150, coarse; DDS Nutrio, Haderslev, Denmark) were used as received.

Storage experiment

Product and packaging. The beef was passed through a 3-cm plate and hand-mixed with the other ingredients for production of three batches of minced beef (each batch size: 18 kg): (**1**) beef plus 1% sodium chloride (serving as reference product); (**2**) 80% beef plus 1% sodium chloride plus 19% rehydrated, texturized soy protein (4% protein, 15% water); and (**3**) 80% beef plus 1% sodium chloride plus 19% rehydrated pea fibre (2% fibre, 17% water) (see Table 1). The mixture was ground through a 0.3-cm plate. The resulting minced beef product was packed in 450-g portions in polyethylene tubes (diameter 8 cm) with an oxygen transmission rate of about 1000 $cm^3 \cdot m^{-2} \cdot day^{-1}$ atm^{-1} (25 °C, relative humidity 75%). The packs were frozen in a blast freezer (air temperature about −35 °C) to a centre temperature of about −10 °C.

Storage. The packs were placed in the upper layer in a freezer cabinet (Gondola, with forced air circulation). Each of the packs was partially covered with black plastic, allowing a direct comparison during storage of the colour of meat exposed to light and meat protected from light. The product temperature was approximately −18° C; however during daily defrosting, the product temperature rose to about −10° C.

Light source. Fluorescent tubes (Philips TLD 18W/92) were used for illumination giving an illuminance of about 800 lx on the surface of the product, where a radiant flux density of 300–400-nm light of about 1.0 $\mu W/cm^2$ was measured.

Table 1. Approximate composition of granulated pea fibre and texturized soy protein and the resulting three minced beef products

	Pea fibre	Soy protein	Amount (%) in minced beef product		
			All-meat (1% NaCl)	With pea fibre	With soy-protein
	(%)	(%)			
Starch	45	30	n.d.	n.d.	n.d.
Dietary fibre	35	2	n.d.	n.d.	n.d.
Protein	11	52	17	15	16
Fat	–	–	24	19	20
Moisture	7	9	58	64	64
Ash	2	7	n.d.	n.d.	n.d.

Information on pea fibre and soy protein were provided by the manufacturer. Minced beef products were analyzed using standard methods. The pea fibre added contained 2% pea fibre and 17% water, while the soy protein added contained 4% soy protein and 15% water. n.d. = not determined

Assessment of lipid oxidation. Lipid oxidation was determined by the direct-extraction thiobarbituric acid (TBA) method of Vyncke [13]. TBA values (mg malonaldehyde/kg meat) were each expressed as means of two analyses.

Colour measurement. The surface colour of the meat samples was monitored during storage by a tristimulus colorimeter (Hunter Lab D-25 with a D25 sensory head) calibrated as described previously [14].

Bacterial sampling. Microbial load was determined during the storage period by spiral counting technique, using the selective plating media described in Table 3 after appropriate serial dilutions.

Model experiment

Preparation of extracts. Hot water extracts were prepared by adding 20 g of the yellow pea fibre product or the texturized soy protein to 60 g boiling distilled water. The mixtures were placed in a waterbath at 80° C for 1 h; 300 g distilled water was added and the mixtures throughly homogenized (Ultra-Turrax T 25). The supernatants were filtered through Whatman 4 filter paper. A blank solution was treated in a similar fashion.

Tests of antioxidant activity. The antioxidant effectiveness of the hot-water extracts was ascertained by determination of thiobarbituric reactive substances (TBA) by the method of Vyncke [13] of beef slices covered by the extracts. Prior to the test, the beef was roasted to an internal temperature of 74° C in an oven preheated to 150° C. The roast beef was sliced into approximately 3-mm slices and 35-g portions placed immediately in 100-ml beakers to which 35 ml extract was added. The beakers were covered with aluminium foil and stored at approximately 2° C in a refrigerator. At specified intervals, samples were removed, the covering solutions decanted and the beef slices tested with thiobarbituric acid.

Results

Lipid oxidation

During freezer storage the amount of thiobarbituric-acid-reactive substances was measured in the center and

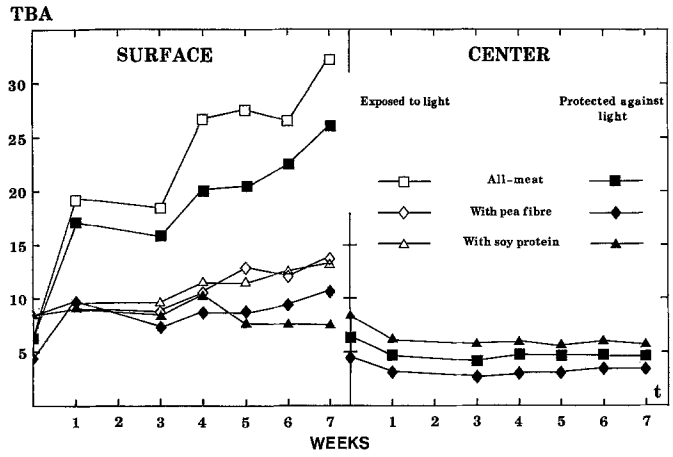

Fig. 1. Lipid oxidation during retail storage in the center and at the surface of frozen, minced beef, measured as TBA value (in mg malonaldehyde/kg product)

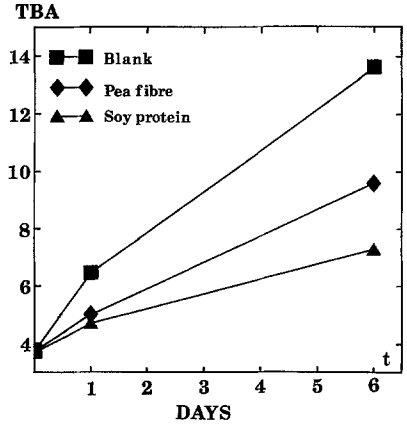

Fig. 2. Antioxidant effectiveness of a hot-water extract of pea fibre and of soy protein as determined by the TBA method and expressed as mg malonaldehyde/kg meat for beef slices covered with the extracts and stored at 2° C

at the surface of the product (≈ 10-mm-deep layer), both for samples stored in the dark and for samples exposed to fluorescent light in the display cabinet. In the center of the product, practically no lipid oxidation occurred (Fig. 1) and the TBA values remained at a constant level of about 5 mg malonaldehyde/kg during storage.

In the surface layer of the reference product (all meat with 1% sodium chloride added), the increase in lipid oxidation was very pronounced, especially for samples exposed to fluorescent light. As may be seen from Fig. 1, the TBA values rose by a factor of almost 6 in the surface for samples exposed to light, whereas the TBA values increased by a factor of almost 5 for the corresponding samples protected against light.

Both the pea fibre product and the texturized soy protein effectively prevented development of rancidity in the surface of the product. This effect was observed both for samples exposed to light and for samples protected against light (Fig. 1); the TBA values for samples with added soy protein and for samples with added pea fibre were not significantly different. Equal protection was accordingly found against lipid oxidation for the tested pea fibre product and for soy protein.

In addition, the water-soluble antioxidant activity of the meat substitutions was tested in a meat model system. The effectiveness in retarding lipid oxidation of a hot-water extract of the pea fibre or of the soy protein was ascertained by determination of the thiobarbituric-acid-reactive substances developed in roast beef slices covered with extract and stored for approximately 1 week at 2° C. As can be seen from Fig. 2, both pea fibre and soy protein were highly effective in inhibiting lipid oxidation in the roast sliced beef. However, the soy protein extract showed significantly higher water-soluble antioxidant activity than did the hot-water extract from the pea fibre product in this assay.

Colour and colour stability

The initial colour of the three minced beef products, as measured by tristimulus colorimetry immediately after freezing, are showed as the Hunter parameters *L*, *a*, and *b* in Table 2. No notable differences in the surface colour was noted between the minced beef to which was added

Table 2. Initial colour of frozen minced beef measured by tristimulus colorimetry and expressed as Hunter *L*, *a*, and *b* parameters

Minced beef product	Hunter parameter		
	L	*a*	*b*
All-meat	28.6	10.5	7.1
Meat with pea fibre	27.1	11.1	7.4
Meat with soy protein	28.4	10.1	7.2

For composition of minced beef products, see Table 1

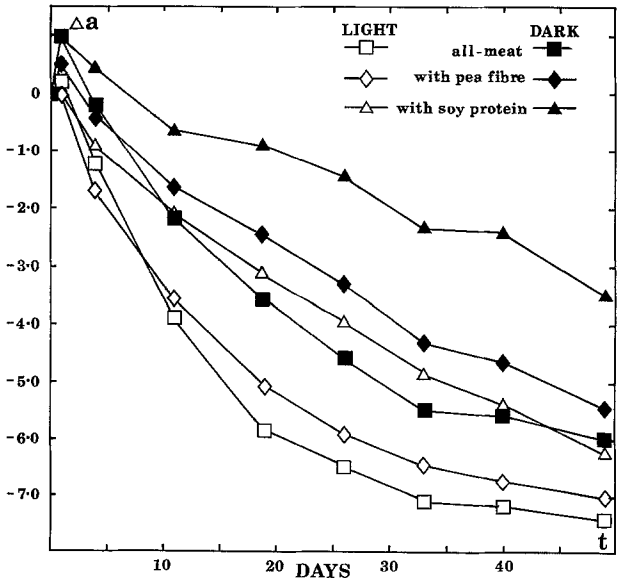

Fig. 3. Colour stability (measured as changes in Hunter *a* value) of frozen, minced beef during retail display in a freezer cabinet with fluorescent light. Product surface exposed to light or rigorously protected against light

soy protein and the reference product, whereas addition of the pea fibre product resulted in slightly higher value of the redness parameter Hunter *a*.

During storage, the Hunter *a* parameter decreased as the product colour gradually changed from bright red to brown. This discoloration was clearly accelerated by exposure to light as may be seen from Fig. 3, in which the Hunter *a* parameter is normalized relative to its initial value ($\Delta a = a(t) - a(t=0)$). The decrease in the Hunter *a* parameter has previously been found to correlate with the progression of autoxidation of the red oxymyoglobin to the brown metmyoglobin [15] and, as may be further seen from Fig. 3, both pea fibre and soy protein yield protection against pigment oxidation. The improvement in colour stability is, however, more pronounced for minced beef with soy protein than for minced beef with pea fibre product added.

Discussion and conclusion

Frozen minced beef products are often extended with soy protein in order to improve the functional properties and to improve the dietary composition with regard to the fat content of the final product. In addition to these advantages, which are common for soy protein and pea fibres, pea fibres have a neutral taste [1]. This is in contrast to soy protein, which has a characteristic off-flavor, described as beany-like or cereal-like [16]. Pea fibre products should, accordingly, be of considerably interest for future use in meat products in which an increased juiciness and a lower fat content are desirable.

The oxidative stability of meat products extended with soy protein is significantly increased during freezer storage. Notably, both pigments and lipids are protected by soy protein against oxidation resulting in a longer practical storage life both with respect to product colour and with respect to development of rancidity. A similar protection against oxidation of meat components is exerted by pea fibre, as demonstrated in the present study. It should be noted that addition of either soy protein or pea fibre did not change product pH or the bacteriological quality of the product significantly during storage (Table 3), the latter being monitored by three standard determinations of microbial load normally used for frozen meat products. Both of the extended products have a lower total lipid concentration (Table 1) but a simple calculation clearly shows that the lower TBA value for the extended products is not purely a dilution effect.

In conclusion, the addition of soy protein or of pea fibre both result in a better oxidative stability of frozen minced beef. Notably, both oxymyoglobin and lipids are protected against oxidation during storage resulting in a better colour stability and in a less significant increase in TBA value. The protection of lipid by soy protein and pea fibre is equally efficient, and the lipid oxidation appears to be prevented for up to 7 weeks of freezer storage. Despite the fact that soy protein yields a better protection against pigment oxidation and consequently a product with a better colour stability, as also demonstrated in the present study, pea fibre may be preferred in many products for other reasons. In this connection it is interesting to note that soy protein and pea fibre yield almost the same relative protection against oxidation of lipids, a protection which is almost independent of exposure to light, whereas the protection of oxymyoglobin is different for the two beef extenders and strongly dependent on exposure to light. These observations deserve to be explored in more detail in relation to the coupling between the oxidative deterioration of meat pigments and lipids.

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Table 3. Microbial content and product pH of minced beef during freezer storage

Minced beef product	Storage time (weeks)	Microbial count, log (CFU/g)			pH
		Total	Faecal streptococci	Coli	
All meat	0	5.4	3.5	2.4	5.8
	4	5.1	2.4	1.8	5.8
	7	5.0	2.2	2.4	5.7
With pea fibre	0	5.5	3.2	2.8	5.8
	4	5.2	3.1	2.3	5.9
	7	5.3	3.0	2.9	5.9
With soy protein	0	5.2	3.1	2.0	5.9
	4	5.2	2.5	2.3	6.1
	7	5.0	2.7	2.9	5.7

Total counts were measured on plate count agar with an incubation time of 72 h at 25° C. Faeçal streptococci were measured on Slanetz agar with an incubation time of 48 h at 37° C. Coli were measured on tryptone/soya agar/violet red bile agar with an incubation time of 24 h at 44° C

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