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ROLLER PEELING OF KRILL

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INTRODUCTION

The stocks of krill (Euphasia superba Dana) in the Southern Atlantic and Antarctic waters occur as vast swarms especially during the austral summer months (Everson, 1977). These stocks provide a potential source of valuable protein for human nutrition and it is currently predicted that commercial exploitation may well occur by the 1980's (Eddie, 1977). It is possible to reduce krill to a protein-rich meal suitable for animal feed, however with a protein resource of such high biological value (Matsumoto et al., 1976) the greatest rewards are likely to be from a product suitable for direct human consumption (Grantham, 1977).

The meat contained in the tail portion is edible and for human consumption it is necessary to separate this meat from the chitinous remainder of the body. Ideally the proteins should not be denatured and the desirable firm texture and sweet shrimp-like flavours should be retained. Undesirable changes in the extracted meats can be minimized by freezing the peeled tails as commercial-style fish blocks. These frozen blocks would appear to be acceptable in international trade and could be processed by a variety of established techniques e.g. fish stick production.

Many of the problems associated with the processing of krill for direct human consumption are due to the size and extreme perishability (Kryuchkova & Makarov, 1969, Hempel et al., 1978) of this species. Krill have the appearance of a small shrimp with an average length of approximately 50 mm and a width of 6 mm. Separation of the tail meat is difficult with a small animal and even with complete separation the yield is of the order of 20%. During processing the appendages i.e. legs, antennae and eyes are readily detached and the exo-skeleton too can break up giving small chitinous pieces. The presence of chitin in extracted meat is undesirable as it gives the product an unpleasant gritty texture.

Within a few hours of catching krill rapidly deteriorate. Visible signs include loss of the natural pink colour, increase in opacity, the exudation of a greenish-brown liquor accompanied by softening and typical odours of spoilage. The powerful proteolytic enzymes found especially in the stomach and hepatopancreas are the reason for most of these rapid changes (Noguchi et al., 1976). In addition the flesh contains a large proportion of highly unsaturated fatty acids. During spoilage the desirable sweet and shrimp-like flavours are lost and after a neutral stage the flavour becomes sour.*

At present the most promising techniques for the separation of tail meat are roller peeling (Hale, 1976, IFOP, 1977) and frozen attrition, although other novel approaches have been tried (Grantham, 1977). Roller peeling is an established

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* The flavour is also affected by the green phytoplankton consumed by krill which causes undesirable bitter flavours in krill products. A method for removal has been reported (Nichiro Gyogyo Kaisha Ltd., 1976).

technique used by shrimp industries throughout the world. Frozen attrition is as yet unproven commercially and the process subject to patents pending. To acquire additional information on the roller peeling of krill trials were performed on a West German freezer trawler in the Scotia Sea and Antarctic waters during the 1977/1978 season. The trials were inevitably limited by the duration of the trip and the availability of krill.

MATERIALS AND METHODS

Peeling was carried out on board the chartered commercial freezer trawler "Julius Fock" using equipment originally designed for the shrimp industry (supplier: Skrmetta Machinery Co. Ltd. New Orleans, La. U.S.A.). In the process krill are taken by a continuous belt conveyor from a storage tank containing sea-water to the peeling unit. The unit comprises nine inclined rubber-coated rollers of 2 m length and 75 mm diameter set parallel and making rotations in alternate opposite directions. Inserted beneath and between these rollers are metal bars of 16 mm diameter. As the krill move down the peeling unit the shell is gripped by the rubber-coated rollers causing extrusion of the tail meat. The exo-skeletons fall into a waste chute and the tail meats are sluiced down the rollers by sea-water from a series of sprays set above the rollers. The flow of krill down the rollers is controlled by rows of spring-loaded plastic "hammers" mounted on a spring-loaded frame performing a vertical reciprocating movement. The extruded flesh is conveyed to a separation unit consisting of ten pairs of inclined metal rollers of length 1 m and diameter 32 mm, each pair rotating at high speed but in opposite directions. The flesh is again sluiced down the rollers by sea-water from sprays and small pieces of shell pass between the gaps of the rollers set at 0.8 to 0.9 mm. In the trials reported the flow of sea-water and the speed of the reciprocating frame were constant unless otherwise stated. It was found necessary to have an operator manually controlling the rate of feed of krill to the peeler.

The krill were caught in the Scotia Sea using a pelagic trawl. Measurements for average length from the head to the end of the telson and ratios of males to females were carried out on each batch by biologists on board the trawler. The amount of feed present in the krill was visually assessed by the green colouration of the thorax. At the time of catching the krill temperature was that of the surrounding sea-water, approximately 0°C. Usually batches of 15 kg of raw krill were processed unless higher throughputs were being investigated when batches of up to 50 kg were used. Batch weights were checked using a spring-balance to within ± 0.5 kg and yields measured on a beam-balance to within ± 5 g. An approximate 150 g sample of the yield was weighed to within ± 0.3 g on a hand-held twin pan balance. The usual problems associated with weighing on a moving vessel were encountered.

The sample of yield was taken to determine the effectiveness of the peeling and separation processes. Counts of unpeeled tails and pieces of shell were made and the presence of eyes or stomachs commented upon. The separation method used was suitable because of its simplicity and relative rapidity. A chemical estimation for chitin would have taken at least 12 hr and could only be performed with difficulty on board a commercial trawler. With the method used it was possible to evaluate product quality and make comparisons between runs.

A portion of the above sample was cooked in aluminium foil dishes over boiling water and the texture and flavour described. Before cooking it was necessary to wash the tails in fresh-water to remove the salt taken up during processing. Although other flavorous substances must have been removed enough residual flavour was left to provide a valid assessment.

RESULTS

1. Influence of delays at ambient temperatures
2. Influence of throughput
3. Influence of storage at elevated temperatures
4. Influence of surfactants

1. Influence of delays at ambient temperatures

It is inevitable that delays will occur between catching and processing of krill. An understanding of the effects of these delays is necessary for a successful peeling process. Batches of krill were stored in baskets and left in the processing area before peeling. During a 24 hr period the temperature of the krill rose from 0°C to 6°C.

Table 1 a Influence of delays on peeling

Time after catching hr	Yield of peeled tails %	Product Quality	
		Unpeeled tails per 100 g	Shell pieces per 100 g
2.5	6.3	2.7	13.3
5.0	7.1	18.2	25.4
8.5	7.9	2.8	12.6
12.5	6.3*	1.7	11.6
22.5	12.7	7.4	19.3

* only one operator

Average krill length 43.5 mm, some feed present, throughput 22 kg/hr.

Fresh sweet shrimp-like flavours were retained for up to 8.5 hr but lost after 12.5 hr. After 22.5 hr definite sour and off-flavours were detected, although the extracted tails had an attractive pink appearance. The poor results for product quality, especially after 5 hr, may be attributable to lack of experience with the operating technique as this was the first trial.

A second trial was carried out with increased throughputs.

TABLE 1 b Influence of delays on peeling

Time after catching hr	Through-put kg/hr	Yield of peeled tails %	Product Quality	
			Unpeeled tails per 100 g	Shell pieces per 100 g
0.7	75	20.5	16.2	63.6
1.5	60	19.6	9.2	61.1
2.7	45	17.3	6.9	38.5
5.3	75	12.0	8.1	71.4
7.7	60	13.5	3.1	56.6

Average krill length 51.0 mm, full of feed.

Many of the krill in this batch were in a pre-moult condition which may account for the high proportion of shell pieces. In addition 69% of the batch were female, many of which were carrying eggs.

2. Influence of throughput

For the type of peeling machine used it is claimed that up to 200 kg/hr of shrimp can be successfully peeled (Skrmetta, 1977). The optimum yield of tails of acceptable quality was examined by varying the throughput.

TABLE 2 a Influence of throughput on peeling

Through-put kg/hr	Time after catching hr	Yield of peeled tails %	Product Quality	
			Unpeeled tails per 100 g	Shell pieces per 100 g
90	2	11.3	0.5	32.4
136	3.5	10.3	1.2	35.3
200	2.7	13.1	3.8	95.4
273	4	9.6	4.5	88.6

Average krill length 50.5 mm, some feed present.

With higher throughputs it was necessary to increase the flow of sea-water.

A further trial was performed with krill full of feed.

TABLE 2 b Influence of throughput on peeling

Through-put kg/hr	Time after catching hr	Yield of peeled tails %	Product Quality	
			Unpeeled tails per 100 g	Shell pieces per 100 g
30	0.7	13.9	3.3	58.0
60	2	-*	30.3	106.1
120	3.5	25.8	13.0	111.0

* not measured as the product quality was so poor. Average krill length 49.9 mm, full of feed.

3. Influence of storage at elevated temperatures

To promote the breakdown of connective tissue between the shell and flesh krill were held at elevated temperatures. Batches of krill were immersed in warm fresh-water and the temperature adjusted by the addition of hot water. Equilibrium was reached after 2 min and the water drained off. During storage the krill were insulated from the lower ambient temperature and the temperature maintained within 2-3°C.

TABLE 3 Influence of storage at elevated temperatures on peeling

Storage temp. °C	Storage time hr	Through-put kg/hr	Yield of peeled tails %	Product Quality	
				Unpeeled tails per 100 g	Shell pieces per 100 g
0.5	0	20	10.3	19.7	37.0
30	1.5	36	3.9	16.2	63.3
35	1.0	20	2.7	3.0	34.8
40	1.0	26	2.2	0	11.4

Average krill lengths 40.3 to 41.8 mm, full of feed.
On tasting there was a loss of sweetness and the desirable shrimp-like flavours for krill stored at 30-40°C.

Cooking prior to peeling is recognized commercial practice in many brown shrimp industries and this process was applied to krill. The krill were heated to 78°C for 5 min or to 94°C for 2 min. In both cases the yield was exceptionally low and so full of shell that measurements were not taken.

4. Influence of surfactants

The influence of surfactants to alter the adhesive properties of the shells was investigated by dipping the whole krill before peeling. Two detergents were used, each at 0.4% concentration, Pril[R] a mixture of anionic and nonionic detergent, and

Dehyquart LDB[R], a cationic detergent (lauryl benzyldimethyl-ammonium chloride). After dipping for 10 min the krill were fed directly to the peeler-conveyor to minimise removal of the surfactants.

TABLE 4 Influence of surfactants on peeling

Treatment	Yield of peeled tails %	Product Quality	
		Unpeeled tails per 100 g	Shell pieces per 100 g
None	12.1	10.7	80.0
Anionic/Nonionic	11.9	6.9	61.1
Cationic	12.7	3.0	39.3

Average krill length 46.4 mm, no feed present.
The surfactants could be dectected in tasting.

DISCUSSION

The effectiveness of the roller peeling process for krill must be considered not just as total yield but also in terms of successful removal of chitinous contamination. A product with a proportion of unpeeled tails or segments of shell has an unpleasant gritty texture. Theoretically the maximum yield of tail meat for the krill processed during these trials was 18-22% (based on the ratio of equal numbers of whole krill to extracted meats), however, none of our trials could achieve these figures without an unacceptable proportion of unpeeled tails and shell.

Due to the design of the machine used it would not be possible to achieve the theoretical maximum yield quoted. An estimated 6% of raw material was lost at the sides of the conveyor belt as the krill were taken to the peeler unit. A similar proportion of extracted meats was flushed out in the waste water of the peeling unit. It was not possible to measure this loss due to the construction of the machine and because it was operated on a moving vessel.

Interpretation of the limited data on the influence of delays before peeling is made difficult by the additional effects of stomach contents, stage of moult and variations in throughput. A comparison between the different tables (relating to different days) is not valid because of these variations and, too, because of the differences in the movement of the ship. In general, it would appear that the product quality, in terms of shell content, is improved by delays up to 8,5 hr, but there is a concomitant loss of desirable flavours during this period.

With the machine used throughputs of over 30 kg/hr gave an unacceptable proportion of unpeeled tails and shells. It was found that a steady flow of krill to the peeler was necessary, otherwise the peeling capacity was temporarily exceeded. Krill could pass down the rollers on top of those being peeled and emerge unpeeled. The steady flow of krill was achieved by an operator controlling the amount and distribution of krill on the conveyor leading to the peeling unit.

The low yields obtained after storage at elevated temperatures were surprising as krill so treated could readily be peeled by hand or machine. It would appear that the adhesive properties of the shell and flesh were radically altered causing loss of flesh between the rollers. As the desirable flavours were also lost this approach is unlikely to be of any commercial significance.

Cooking altered the physical characteristics so radically that the krill could not be peeled successfully. This was unexpected especially as cooking is standard practice before peeling brown shrimp. Further work is necessary here to investigate this anomalous behaviour.

Attempts to alter the adhesive properties of krill by the adsorption of surfactants did not improve peelability and the additives could be tasted in the product.

CONCLUSIONS

Using commercially available equipment roller peeling of krill is technically feasible. Freshly caught krill should be processed within 8 hr of catching to minimise the loss of desirable flavours, although a short delay does facilitate peeling. In general a throughput of 30 kg/hr gave an acceptable product with the minimum amount of shell, however the rate at which krill enter the peeling unit must also be controlled for optimum peeling.

The yields obtained and the throughput achieved in these trials will not be representative of what may be possible with equipment constructed specifically for krill, therefore any calculations of economic estimates based on this data are likely to be misleading. A machine designed specifically for small animals may give better yields by minimising losses during processing. Further improvements would be obtained by mechanically controlling the feed rate to the peeling unit and by using fresh-water for sluicing the extruded tails.

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REFERENCES

Eddie, G. (1977) GLO/SO/77/2, FAO, Rome.

Everson, I. (1977) GLO/SO/77/1, FAO, Rome.

Grantham, G.J. (1977) GLO/SO/77/3, FAO, Rome.

Hale, I.F. (1976) Fish. News Int. 15 (10) 72.

Hempel, W., Sahrhage, D., Schreiber, W., and Steinberg, R. (1978) Arch. Fischwiss. 29 (Beiheft 1) 1.

IFOP, Desarrollo de là pesquera del krill (1977) p. 20. Santiago de Chile.

Kryuchkova, M.I. & Makarov, O.E. (1969) Rybnoe Khozjajstvo, 66 295.

Matsumoto, K., Chokki, S., Hamakura, D., Maekawa, A. & Suzuki, T. (1976) J. Jap. Soc. Fd Nutr. 29 307.

Nichiro Gyogyo Kaisha Ltd. (1976) Jap. Pat. App. 30181/75; West German Pat. No. 2610095 (1976).

Noguchi, N., Yanagimoto, M., Umedo, K. & Kimura, S. (1976) J. Agr.Chem. Soc. Jap. 50 415.

Skrmetta, R. (1977) Personal Communication.