Processing and Products of Japanese Quince (*Chaenomeles japonica*) Fruits

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SUMMARY

In this paper, applied research on the usefulness of Japanese quince (*Chaenomeles japonica*) fruits in processing and for development of products is reported. Juice was extracted by crushing and centrifugation or by pressing, with and without prior treatment with pectolytic enzymes. Aroma was extracted from fresh fruits by sugar and was also enriched by pervaporation from juice. Several products were developed based on fruit juice, purée and aroma extracts, including consumer products such as chaenomeles ice cream, lemonade, jam, curd and yoghurt.

Pectin extracted from Japanese quince fruits was tested in baking of white bread. The pectin was found to be highly useful in improving bread quality, and had a positive effect on crumb hardness and elasticity. A dosage of only 0.5% of flour weight resulted in a 7% increase in bread volume. The potential of using chaenomeles pectin in baked goods would therefore be good if it was possible to produce pectin in a way that resulted in a cost-competitive product.

INTRODUCTION

Without preliminary knowledge of the prospects for industrial processing and commercial product development, it is impossible to justify long lasting and expensive research aimed at introducing new crops. This is especially important for plant breeding programmes focusing on perennial crops, where the development of a new variety may take 20 years or more. Furthermore, it is unlikely that a new crop will ever be successfully introduced if growers, consumers and the industry are not aware of its potential.

Japanese quince (*Chaenomeles japonica*) is considered to be an interesting plant because of its high yield of acid fruits, which are also rich in fragrance and flavour (Rumpunen 2002). The low habit and the healthy plant also make the crop interesting for organic farming systems. A few products (*e.g.* syrup and liqueur) have previously been produced from Japanese quince fruits on an industrial scale in Latvia and Lithuania (Ruisa 1996). Furthermore, research in Poland (Lesinska 1986) indicated that Japanese quince fruits could be interesting for a range of other products *e.g.* ice-cream, jam and blended juice. Initial studies of the fruit biochemistry of Japanese quince suggested that the unique flavour and the high content of dietary fibre should be emphasised. Therefore, the potential of Japanese quince fruits was further evaluated from a processing viewpoint and several products were developed.

PROCESSING AND PRODUCTS

Extraction of chaenomeles juice

The content of juice is high in Japanese quince fruits despite the firm fruit flesh. Juice was extracted by pressing and by centrifugation, both in the laboratory and on pilot plant scale. The yield of juice depended largely on the procedures and equipment employed.

Japanese quince fruits have a high content of seeds (up to 10%). Initial tests found that when a large fraction of the seeds were crushed, an off-taste appeared in the flavour of the extracted juice. As a first processing step the fruits were therefore divided into halves and seeds were removed. Then fruit flesh was crushed and the juice was extracted by pressing or by centrifugation. Using this procedure the juice yield was 40–60%. This juice was cloudy, in contrast to juice obtained by an ordinary table extractor (centrifuge).

To further increase the yield of juice, different commercial enzymes were tested. The juice obtained from an initial extraction of fruits was mixed with the residual pulp fraction and incubated with the enzyme preparation at room temperature overnight. After incubation, the juice was exhaustively extracted from the mash. The characteristics of the juice extracted with and without enzymes are shown in Table 1.

When enzymes with high pectolytic activity were used for extraction, the yield of juice increased to 70%. In addition, pH, content of soluble solids, density and turbidity increased. However, the content of vitamin C in the juice decreased from 102 to 63 mg/100 ml. Thus, procedures for juice extraction using enzymes should be further improved so that if possible, a high content of vitamin C is preserved in the juice at the same time as a high yield of juice is obtained.

Thermal treatment of chaenomeles juice

Fruit juices are often heated to eliminate micro-organisms and to inactivate endogenous enzymes. Without a thermal treatment a loss of quality of the juice during processing may occur and the shelf life of the products is usually shortened. When chaenomeles juice was heated to 90 °C for 10 min, no changes were observed in its characteristics (pH, °Brix, NTU, etc.) or in the content of vitamin C. Further research should be performed to establish the optimal conditions for heat treatment of consumer products.

Concentration of chaenomeles juice

Fruit juices are sometimes concentrated to allow cheap transport and rational handling during processing. Concentration may also help to preserve the quality. As a preliminary study, chaenomeles juice was concentrated on laboratory scale using a rotational evaporator at a temperature of 40 °C and a vacuum of 40 mbar. The characteristics of the juice were measured before and after concentration.

It was possible to concentrate the chaenomeles juice as much as nine times, to a final content of soluble solids of 70 °Brix (Table 2). The values of the characteristics of the juice (pH, density, soluble solids, etc.) were typical for a clear concentrated juice. By concentration, the content of vitamin C increased from 96 to 1048 mg/100 ml and the pH decreased from 2.8 to 1.8. The stability during storage in different conditions should be further evaluated.

Table 1. Characteristics of Japanese quince (*C. japonica*) juice extracted with and without enzymes (Ultrazym 100 G, Novozymes).

	pH	Density (g/ml)	Soluble sugars (°Brix)	Viscosity (cP)	Transmittance (%)	Turbidity (NTU)	Yield (%)
Without enzymes	2.9	1.028	8	1.13	96	9.5	40
With enzymes	3.2	1.063	17	1.15	73	38	70

Table 2. Characteristics of Japanese quince (*C. japonica*) juice before and after concentration.

	pH	Density (g/ml)	Soluble sugars (°Brix)	Viscosity (cP)	Transmittance (%)	Amount (g)
Fresh juice	2.8	1.028	8	1.13	93	590
Concentrate	1.8	1.357	70	53.20	89	69

Pervaporative aroma recovery from Japanese quince fruit juice

The aroma in skin, flesh and juice of Japanese quince fruits constitutes an essence, which is a solution of aromatic components in water, and not an essential oil. Therefore technologies developed for essence enrichment, such as the use of pervaporative membrane methods, seemed interesting to test on chaenomeles juice. Previously, apple aroma in apple juice had been successfully enriched using this technology (Olsson 2001). Different membranes and processing conditions were studied to optimize procedures for aroma enrichment of samples of chaenomeles juice (Irmer 2000). Chaenomeles juice was obtained from flesh treated by different enzymes before extraction, and 5% ethanol was added to one sample to increase fluxes. Volatile components were detected and identified by a gas chromatograph coupled with a mass spectrograph. In addition, a sensory evaluation was performed of the samples.

In the study, total fluxes through the membrane were nearly identical for the different samples, 59.4–60.8 g/m^{2}h. Only the sample to which ethanol was added had a higher flux, 84.6–85.0 g/m^{2}h. However most of this difference could be attributed to the alcohol added. The best result was obtained when the fruit juice was extracted by pectinases. Therefore, in the future more research should be devoted to optimising the conditions for enzymatic treatment during extraction. This will most likely result in an increased amount of aroma components in the juice. The addition of ethanol to the juice increased partial flux for many components and concentrations should be optimized. Analyses by gas chromatography revealed enrichment of many volatiles. However, in sensory evaluation the typical fragrance of fresh chaenomeles fruits was absent, which could be partly explained by a relative loss of highly volatile components during juice extraction and not the pervaporation process *per se*. The study shows that pervaporation could be a promising technique for the recovery of chaenomeles aroma from chaenomeles juice but more research is needed before pervaporation can be introduced into commercial production.

Chemical and enzymatic peeling of Japanese quince fruits

In industrial production of consumer products, peeling of fruits is often a necessary first processing step. Therefore possibilities for chemical and enzymatic peeling of Japanese quince fruits were studied. For chemical peeling 1% NaOH was used, whereas for enzymatic peeling Ultrazym 100 G at a concentration of 5 g/l in 0.1 M citric acid (pH 2.0) was used. However, neither the chemical nor the enzyme treatment was successful in removing the peel of Japanese quince fruits. Instead mechanical peeling in combination with hot water may be proposed for peeling.

Canned chaenomeles fruits

A procedure for production of canned chaenomeles fruits was developed. Halved fruits without seeds were put into glass containers. Chaenomeles fruit juice with sugar added in amounts corresponding to 20 °Brix and 1000 ppm calcium (added as calcium chloride) was used as canning liquid. For canning, the sugar-calcium liquid was heated to 60 °C and poured into the glass jars. The glass jars were closed and heated in a hot water bath at 90 °C for 10 minutes. Sensorial properties of the fruits, pH and the content of soluble solids in the liquids were evaluated during storage for 10 months (Table 3).

Table 3. Changes in the characteristics of the canning liquid during storage of canned Japanese quince (*C. japonica*) fruits.

Month	1	4	10
pH	2.7	2.6	2.5
Soluble solids (°Brix)	18.0	17.8	18
Density (g/ml)	1.063	1.065	1.061
Turbidity (NTU)	173	223	159
Transmittance (%)	55	40	58
Browning	No	No	Yes

During storage the pH slightly decreased but the content of soluble solids was stable at 18 °Brix. The content of vitamin C in the canning liquid increased to 130% of the content in fresh juice. Fruit browning occurred during later stages of storage but the texture of the product was good and the taste was pleasant but somewhat acidic. Therefore, it is suggested that in consumer products the sugar content of the canning liquid should be increased to approximately 25 °Brix. Canning preserves the nutritional properties of the fruits, and the product could be directly consumed as a dessert and in confectionery, etc.

Chaenomeles conserve

A widely appreciated product in the Mediterranean countries, traditionally made from quince (*Cydonia oblonga*), is "carne de membrillo" (quince conserve). Following an old Spanish recipe for cooking quince conserve, a chaenomeles conserve was produced. Fruits were washed, peeled, cut into small pieces and seeds were removed. The pieces of fruit flesh were put into a pan and some water was added. The pan was brought to boil and was allowed to simmer for a few minutes. Sugar was added (approximately one part sugar by weight for each part of fruit flesh) and the conserve was gently cooked with continual stirring until the desired texture, dryness and colour were achieved. The conserve was then poured into a mould and chilled before being served. About 5 kg of chaenomeles conserve was prepared, packed under vacuum and stored with good stability. The chaenomeles conserve had a pleasant taste and a good texture. Other ingredients that may be included in the recipe are *e.g.* cinnamon or ginger. Chaenomeles conserve could ideally be served with ice cream, cream, yoghurt or creme fraiche.

Chaenomeles syrup

Different procedures were tested to extract the unique flavour in chaenomeles fruits as efficiently as possible. The use of pure sugar for osmotic extraction was very easy and at the same time most efficient in preserving the chaenomeles flavour. For this purpose the fruits were cut into slices approximately 1 cm thick, and the seeds were removed. The fruit slices were then covered by an equal amount (by weight) of sugar and stored in a refrigerator for one day. As a consequence of dehydration, the fruit slices shrank (to approximately 3 mm) and a lot of juice was extracted from the fruits. The resultant syrup had a very nice flavour and fragrance, and was used as a flavouring in various products, *e.g.* in a ripple used to flavour ice cream, in a soft drink, in lemonade and in a liqueur.

Candied chaenomeles fruits

Candied fruits are much appreciated in most Western countries and the acid fruits of Japanese quince were considered suitable for this kind of product. Chaenomeles candy was produced from sliced fruits (seeds removed) which were frosted with a 60 ºBrix syrup for two hours in 60 ºC at 60 mm Hg vacuum. The fruit slices became partially dehydrated and developed a darker colour. The sweet and acid slices were considered a tasty product.

Chaenomeles fruits in brine

Vegetables and fruits preserved in brine and flavoured with acids, oils and grasses are used assiduously by the industry. Therefore the possibility of preserving chaenomeles fruits in brine was studied. Fruits were divided into halves, seeds were removed, and the fruit halves were put into brine of increasing strength, starting at 7.5 ºBaumé. The strength of the brine was increased by 3 ºBaumé every second day until a final concentration of 18 ºBaumé was obtained. The fruits were kept at the final concentration for four weeks and the product was then evaluated. This treatment gave fruits an attractive appearance, a palatable taste and a good texture. Chaenomeles fruits in brine would therefore be an interesting product that may be further developed in the future.

Chaenomeles curd

Lemon curd is a well-known product in many Western countries and it was anticipated that chaenomeles fruits would be useful as a flavouring in a similar product. For this purpose a traditional recipe was followed, and chaenomeles purée was added instead of lemon juice /peel. The ingredients used were 3 eggs, 150 g sugar, 100 g chaenomeles purée and 50 g butter. The eggs were mixed with sugar and warmed over a low heat until the mixture thickened. Chaenomeles purée was added together with butter, and the curd was stirred until the butter had melted. The product was then poured into jars. This product was really tasty.

Chaenomeles jam

Chaenomeles jam was produced in many different ways, with and without mixing with other fruits (*e.g.* apple, strawberry, rose hips). A useful recipe for a standard chaenomeles jam developed consisted of 500 g sugar, 200 g chaenomeles purée, 150 g fresh chaenomeles fruits cut up to pieces, 140 g water and 6.5 g pectin. The sugar was mixed with purée and water, then pectin and the fresh pieces of chaenomeles fruits were added, and the jam was brought to the boil for a few minutes. Finally the product was poured into jars. Following this recipe, a yellow jam with fruit pieces and a strong taste of Japanese quince was produced. If a less intense product is wanted, it is recommended that some of the chaenomeles purée be replaced with apple.

Evaluation of dietary fibre and pectin in baking of white bread

In industrial baking, dietary fibre from many sources is added to improve dough consistency and nutritional properties of bread. Commonly pea fibre and oat fibre are used but fruit fibre from *e.g.* apple and lemon is also suitable for this purpose. Since the content of dietary fibre and pectin in chaenomeles fruits was found to be high (Thomas *et al.* 2000, Thomas & Thibault 2002) it was interesting to evaluate their effect in baking of bread. At the beginning, unpurified fibre residues obtained from juice extraction were tested. Later AIS (alcohol insoluble substance) and pectin extracted from the AIS were tested. Test bakings were performed following standard procedures (Table 4), in which chaenomeles fibre replaced part of the wheat-flour in white bread.

Raw chaenomeles fibre residue was detrimental for bread quality (results not shown). This was probably to a large extent due to the high acidity of the residue obtained from juice extraction. Therefore more pure fibres were developed and evaluated. As the purity of the chaenomeles fibres increased, the negative effects on baking decreased, and when pure chaenomeles pectin was used a very positive effect was obtained for many of the bread quality parameters evaluated (Table 5). At the very low dosage of 0.5% of flour weight, bread volume increased by 7% compared to the control. A very important quality parameter of bread is the softness and elasticity of the crumb, which are perceived by the consumer to be a measure of the freshness. Softness and elasticity were estimated using a Stable Micro Systems Texture Analyzer. The method used was the AACC-method, which gives the hardness of the crumb in grams and the elasticity in percent as a relationship between the resistance at maximum penetration of the probe and

Table 4. Recipe for white bread with fibre (AIS and pectin) extracted from Japanese quince (*C. japonica*) fruits.

	Control	AIS (1%)	pectin (0.5%)
Wheat-flour 23 ºC	850	800	825
Water 30 ºC	500	500	500
Yeast	50	50	50
Margarine	15	15	15
Sugar	15	15	15
Salt	15	15	15
Japanese quince fibre	0	9	4.5
Total:	1445	1404	1424.5
Dough amount	1430	1395	1415
Dough mixing	1+4 min	1+4 min	1+4 min
Resting time	30 min	30 min	30 min
Dough temperature	27 ºC	27 ºC	27 ºC
Loaf weight	500 g	500 g	500 g
Proofing time	40 + 5 min	40 + 5 min	40 + 5 min
Baking time	22 min	22 min	22 min
Baking temperature	200 ºC	200 ºC	200 ºC

Table 5. Effect on dough consistency and bread quality when wheat-flour was replaced with 1% AIS (alcohol insoluble substances) or 0.5% pure Japanese quince (*C. japonica*) pectin.

	Control	AIS (1%)	pectin (0.5%)
Dough consistency	swt rigid	swt sticky	normal
Dough after 30 min	normal	swt sticky	very smooth
Dough structure	normal	stippled	normal
Dough colour	normal	swt brown	brown
Stability (rise)	normal	swt weak	normal
Bread volume	2110 ml	1980 ml	2270 ml
Bread shape	normal	swt flat	normal
Shape height/ width	76/140 mm	69/145 ml	77/150 ml
Bread crumb	dense	swt uneven	dense
Crumb colour	white	light brown	yellowish
Bread surface	gold-brown	grey, stippled	brown
Crumb consistency	soft	soft	soft
Chewing onsistency	normal	normal	normal
Bread taste	normal	acid	swt acid
Bread smell	normal	fruit	faint fruit
Fibre taste		dried fruit	acid, pungent
Fibre colour		brown-pink	swt brown

the resistance when the probe has been held at that penetration for 32 seconds. For hardness the value should be as low as possible and for elasticity it should be as high as possible for this kind of bread. The measurements of hardness and elasticity showed that the addition of AIS had a negative effect (Table 5), probably more negative than can be accounted for by its negative effect on bread volume and thereby density. However, the effect of the pure chaenomeles pectin was very clear and very positive, both for hardness and for elasticity. Some of the positive effect for hardness can be explained by the positive effect for bread density but it cannot explain all. Based also on experience from bakings with other fibre and pectin, it seems that pure chaenomeles pectin has a very powerful and positive effect on crumb hardness and elasticity. Such a large effect, at a dosage of just 0.5%, is in fact the largest we have ever seen from any fibre supplement to bread. The potential for chaenomeles pectin in baked goods is therefore very good if it is possible to produce the fruit and extract the pectin in a way that gives a competitive product.

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