CHAPTER 9

PROFITABILITY OF ‘READY-TO-EAT’ STRATEGIES

Towards model-assisted negotiation in a fresh-produce chain

HANS SCHEPERS[#] AND OLAF VAN KOOTEN[##]

[#]Agrotechnology and Food Innovations, Wageningen University and Research Centre, P.O. Box 17, 6700 AA Wageningen, The Netherlands. E-mail: Hans.Schepers@wur.nl
[##]Horticultural Production Chains Group, Wageningen University and Research Centre, Marijkeweg 22, 6709 PG Wageningen, The Netherlands

Abstract. With help of a simple System Dynamics model describing purchase frequency of consumer segments, we illustrate under which circumstances a scenario of ‘ready-to-eat’ positioning creates value for retailer, trader and grower in a fruit production chain. Although fully quantified, the model is meant as a discussion support tool. It illustrates how collaboration affects the pay-offs of innovation for each trade partner. We show how negotiations addressing other factors than prices optimize total chain profit and hence profit per player. These factors include ready-to-eat positioning, the variation in product ripeness within batches, and cost-sharing agreements regarding product loss and the promotional budget.
Keywords: mathematical modelling; product positioning; consumer behaviour; willingness to innovate; economics of collaboration

INTRODUCTION

Innovation in chains poses dilemmas: taking action by one player influences other players’ profitability, or the profitability of other players’ collaborative or competitive actions. For example, actions may only be marginally effective unless other players proceed with complementary actions. Improving the quality of perishable produce by the supply chain in order to stimulate consumption is thwarted when the retailer uses the longer shelf life to ship products to more distant locations in order to compete there for new volume, based on less ‘fresh’ product. Therefore, timely discussions on potentially innovative value-creating options between chain (e.g. trade) partners can maximize total extra profits to the chain players involved, and prevent loss of pay-off of innovations due to intra-chain competition. Such discussions require that the often implicit assumptions necessary for the (financial) implications of the projected innovations are made explicit. For

C.J.M. Ondersteijn, J.H.M. Wijnands, R.B.M. Huirne and O. van Kooten (eds.), Quantifying the agri-food supply chain, 117-132.

many operational processes such as logistics, detailed quantitative models are used to calculate new profits and optimal design choices. However, for a product repositioning (e.g. ready-to-eat fruits), various factors that are difficult to quantify – let alone predict – such as consumer perceptions of product quality and effectiveness of promotions, are vital to address. This adds a substantial amount of uncertainty and leaves much room for misunderstanding, based on differing perspectives, expectations and experiences regarding the effectiveness of possible marketing actions. Our hypothesis is that *especially* in such situations, modelling these assumptions and possible mechanisms behind changed consumer behaviour improves the strategic discussions, and is instrumental in increasing the success rate of the innovations involved. However, in contrast to the applications in well-quantified fields such as logistics, not many tools and basic mental models exist to analyse the potential effect of innovations involving consumer behaviour. Here, we model the effect of ready-to-eat positioning of fresh exotic fruits on the potential consumed *revenues* (in contrast to cost levels) for each player in the chain. Very quickly however, we encounter the main hurdle: product loss. It is due to the combined modelling of product loss and the newly generated revenues that the model can point to viable collaborative chain arrangements that facilitate optimal profit for each player.

Exotic fruit case

Supply chains can minimize product loss of exotic fruits (e.g. mangoes) and stone fruits (e.g. fresh peaches) by harvesting and selling at a quite early (unripe) development stage. However, this also means that consumers should let the fruit ripen at home for a number of days before consuming it. In practice, they may lack the patience to let the fruit properly ripen, and consume it while it does not yet have the taste and texture properties they actually value and expect. As a result, a fraction of disappointed consumers remain in a stage of 'low frequency' usage. Our hypothesis is thus that too strict application of agro-logistics expertise focused on minimization of product loss may negatively impact the volume of consumption.

Clearly, winning consumers for fresh exotic produce is a complex and difficult task. Pricing, promotion and product quality are among the driving forces that increase consumption. Thus, the distribution of fresh but perishable produce has to meet more conditions than just a swift response to the change in quantity of products bought by consumers as for instance 'Efficient Consumer Response' aims to do. Much additional effort is involved in preventing quality loss during storage, transportation and display on the retail shelves. Parameters such as storage timing and especially temperature regimes can be chosen in a way either to minimize product loss, to meet or exceed expected quality at the retail shelve, or to cover a larger geographical distance between the producer's and retailer's locations. In addition, store-front parameters, such as packaging and the display regime (last-in-first-out, first-in-first-out) are important controllable parameters, in order to ensure timely sales of produce before quality loss hampers the attractiveness to consumers. Finally, discounting on the retail price just prior to the use-by-date (explicit or implicit) provides an additional measure. In that case, the variation in freshness within a batch of products is communicated explicitly and used to the advantage of both consumers and retailers.

Here we present a system-dynamics model that should help to explore the effectiveness of the various tactical marketing decisions for product positioning, promotions and pricing. The consumption of mangoes is used as an illustrative example. The model allows one to study incentives of each chain player to benefit from such marketing efforts. For example, sharing cost of promotion between trade partners makes it possible to identify situations where neither player would innovate on its own, while through a cost-sharing agreement they both benefit sufficiently from marketing efforts. By capturing generic dilemmas of post-harvest product handling, marketing and chain collaboration, we can learn how these innovation efforts are best combined. Steady-state analysis and optimization techniques are used to generate optimal innovation policies for retailers and producers.

THE MODEL

The model integrates heuristics from three disciplinary domains, viz., consumer science, quality management and chain management, as illustrated in Figure 1.

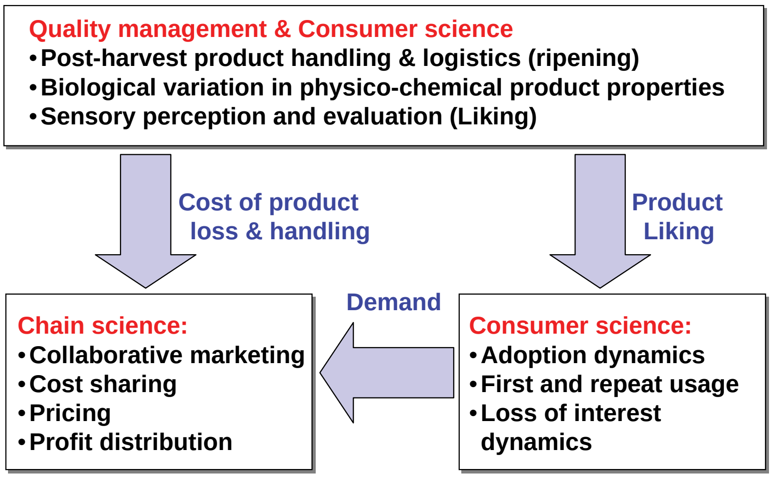

Figure 1. *Three research fields provide components of the model. The linking variables are indicated with arrows*

Quality management aims to provide an attractive product to consumers at minimum cost for product handling and cost for product loss. Consumer liking drives usage dynamics and thus provides ‘demand’. Within chain-management science, collaborative marketing, involving smart pricing and cost sharing can yield the right incentives for chain players (in our case the retailer and its trade partner, here called ‘producer’) to realize a viable business, and ultimately employment, in the exotic-fruits sector.

The time scale of strategic interest to the chain players is assumed to be medium term, i.e., around four years. Since consumer adoption is a dynamic process that takes place on that time scale, it is explicitly translated into differential equations that lie at the heart of the model. Faster processes (e.g., generation of product loss and cost) are translated into auxiliary variables that are determined by other variables and parameters. Slow determinants or processes are represented as constant parameters (e.g., unit handling cost, consumer preferences, price elasticity). For generic system-dynamics modelling as applied to business strategy and practice, see Sterman (2000).

We present the three sub-models in the following paragraphs, and refer to Appendix 1 for the formal mathematical equations.

Modelling consumer-behaviour matters

The sub-model describing consumer behaviour is a first-order compartment model for consumer segments: non-users (N), low-frequency, 'occasional' users (L) and high-frequency, 'loyal, repeat' users (H), shown in Figure 2.

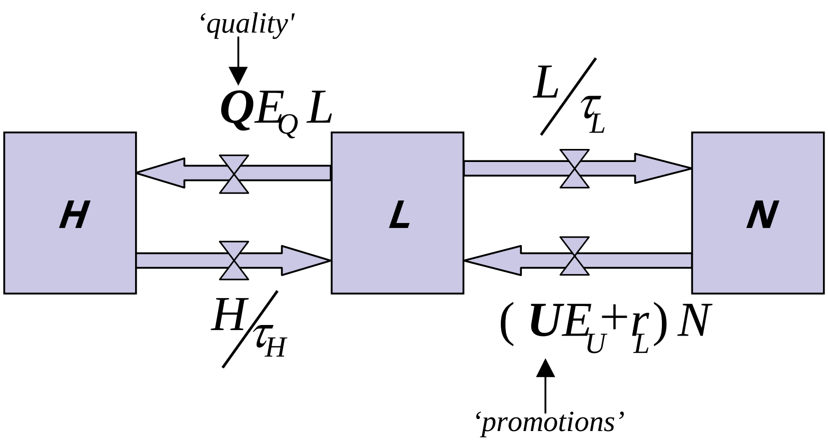

Figure 2. *The consumer sub-model consisting of three product adoption segments*

Promotions (U) and Product quality (Q) modulate different rates of adopting a more frequent product usage. The transition from non-user (N) to occasional user (L) is assumed to occur either spontaneously or under the influence of 'promotions' (U). The development of product loyalty, i.e. the transition from occasional user (L) to repeat user (H) is driven by Liking, which is defined below. When the product does not elicit Liking, occasional users (L) fall back to non-users (N) with a constant rate. For completeness, also loyal consumers may lose interest and 'fall back' into the state of occasional user (L), with a constant rate. How these processes are affected by quality, price and promotions is not included in the present model. Promotion and 'offering the right quality' are the two main instruments to obtain many and loyal customers, respectively. Note that this part of the model describes the intended usage frequency only, not the actual buying frequency, which depends on the price encountered in the store, governed by a standard price-elasticity curve. This 'standard' treatment of the effect of price is included in the computation of volume sold (see Appendix 1).

Modelling quality matters

On the product-handling side of quality management, we allow for a substantial amount of biological variation in the ripeness of fruits at the moment of harvest. For simplicity, this variation remains constant during transportation and storage. Technologies may exist to reduce the variability within a batch, e.g. by sorting. This affects the product-loss rate on the supermarket shelves as well as the Liking, as will be shown below.

Liking is modelled here as the extent to which consumers find what they expect in the product offering. For simplicity, the attribute space spanning relevant product properties was taken as one-dimensional ('ripeness'), which is intended to correspond to the first principal component of a full collection of product attributes. The Liking curve can be thought of as a demand curve: in our case a function of the 'objective' product quality characteristics (i.c., ripeness), instead of a function of price. For exotic fruits, it is assumed to be bell-shaped, with an optimum ripeness and a relatively large region of tolerance for ripeness around it. The Liking curve thus also reflects the various preferences of consumers based on 'optimal taste', combined with the duration consumers may wish to store the fruit at home before consuming it. For various forms of the Liking curve, see Schepers et al. (2004).

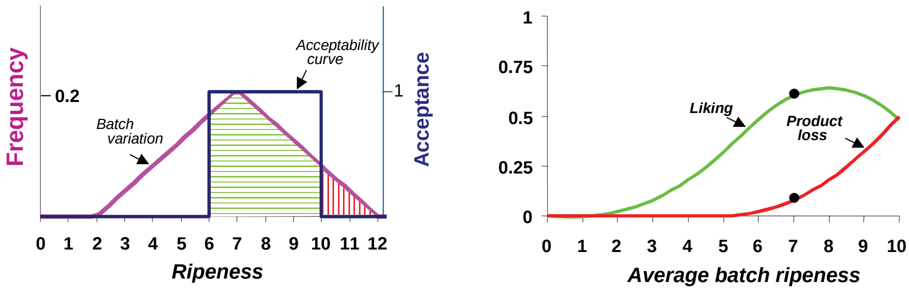

***Figure 3**. Ripeness, Liking and product loss*

Ripeness is represented on an arbitrary scale from 0 (unripe) and 10 (start of over-ripe). Mangoes having a perceived firmness above 10 are considered to be over-ripe and unsuitable for consumption: therefore the starting point for product loss, as the mangoes cannot be sold anymore. In the simplest case, illustrated in Figure 3, consumer liking is modelled with a uniform Liking function ranging with a lower limit (minimum ripeness) of 6 and a maximum acceptable ripeness of 10. In Figure 3 (left-hand panel), an alternative definition of product quality is given by mapping both the distribution of *supplied* product property (ripeness, 'objectively measurable') and *demanded* (expected, appreciated ripeness) product properties ('subjectively perceived attribute') into the relevant attribute space. We define Quality (Q in the Appendix) as the overlap, indicated as the horizontally shaded area; mathematically, the integral of batch variation distribution function and the Liking function. At the same time, the product-loss fraction is automatically defined as the integral (W in the Appendix) of the variation distribution function above the cut-off point (here at 10), indicated by the vertically shaded area. How product loss increases with average batch ripeness is also shown on the right-hand panel. The batch variation causes the product loss to rise when the average ripeness increases.

In order to quantify the cost of providing fruits of various ripeness levels, we assume that the time it takes for the fruits to ripen from one stage to the next is one day, of yet unspecified treatment. More elaborated models for ripening speed as function of temperature and specific technologies, such as using ethylene or various forms of packaging, can be coupled at a later stage.

Modelling chain-behaviour matters

In order to model how chain players can collaborate to provide the right product quality, *given* the preferences and the familiarity of consumers with the product, the sub-models for both the dynamics of the consumer segments and that of the quality perception are combined. Subsequently, we compute the financial implications (e.g., profits Y) of the marketing strategy for each of the three players in the chain: the retailer (index r), the trader or importer (t) and the producer or exporter (p). A subscript (c) denotes the summed profits of the retailer and the trader. Profits are reported with dimensions euros (€) per week, and could represent the profits for one supermarket or outlet (numbers are thus quite low). The profits Y_r, Y_t and Y_p are straightforward functions of prices, the volume and the unit cost level for the producer C_p, for the retailer, handling costs per day C_{hd} and per fruit C_{hp}, and the product-loss fraction W. The equations are described in Appendix 1. For causal diagrams and a Stock & Flow representation of the model, we refer to Schepers et al. (2004). One extension, and implicitly a correction, from Schepers et al. (2004) concerns the allocation of the cost of product loss (the case described in that paper is an illogical special case of the following generic form): we here define the fraction f_w of the cost of the volume that is wasted as product loss the retailer has to pay for (to the trader). In certain product groups, e.g. milk, the retailer returns the unsold products to the manufacturer, who pays back (part of) the volume. In such cases, f_w would be zero or at least below 1, whereas for fresh produce, today, the retailer is not reimbursed for unsold volume, and f_w is 1. Table 1 presents the parameters, symbols and values. The initial conditions are set at the analytically computed steady-state level corresponding to the other parameter constants.

Another chain management instrument already present in the model is the fraction of joint product-promotion budget provided by the trader, u_t. Other parameters on which negotiations/bargaining may take place are the transfer prices P_{rt} and P_{tp} and the amount of variation in ripeness within a weekly batch of fruit, v. This important parameter determines to a large extent the product loss and, as we shall see, the extent to which consumers' expectations are met, resulting in better or worse quality.

***Table 1**. Parameter constants and initial conditions*

	Parameter	Symbol	Value	Dimension
Producer / trader	production unit cost	P_{tp}	0.25	€/piece
	trader share in promotion	u_t	50%	-
	promotion budget (chain cost)	U	65	€/week
Retailer	variation	v	5	days
	freshness deadline	m	10	days
	product positioning	T	5	days
	handling cost per day	C_{hd}	0.005	€/piece/day
	retail fixed handling unit cost	C_{hp}	0.1	€/piece
	purchase price	P_{rt}	0.5	€/piece
	price positioning	d	1	-
Consumer	minimum acceptance	a	6	days
	time scale to stop using ($L \rightarrow N$)	τ_L	26	weeks
	time to lessen consumption ($H \rightarrow L$)	τ_H	52	weeks
	total number of consumers	Z	10000	persons
	initial number of occasional users	$L(0)$	2680	persons
	initial number of repeat users	$H(0)$	669	persons
	consumption occasional user	D_L	0.02	pieces/(week* person)
	consumption repeat user	D_H	0.3	pieces/(week* person)
	quality effect of frequency	E_Q	0.015	1/week
	price elasticity	e	-3	-
	reference price	P_{cr}	1	€/piece
	promotional effectiveness	E_U	0.0002	1/€
	fraction spontaneously trying anew	r_L	0.0025	1/week

RESULTS

We here present a limited set of instruments the producer and retailer have, to influence consumer behaviour and to optimize their economic return. In this exemplary study, the average firmness T is used by the retailer to influence the transition of occasional (L) users to repeat users (H). Both retailer and producer gain a profit from promotion U to enhance the transition of non-users (N) to occasional users (L). But the retailer and producer may bargain about their share of the promotion costs they contribute. Equally, the share of the product-loss cost (f_w) (reimbursement) will be shown to modulate the incentives to proceed on adjusting other important parameters, notably the variance in ripeness within each weekly batch, which is most relevant for a profitable ready-to-eat strategy.

The main use of the model in its current unvalidated state is as discussion support tool, aiming at discussing qualitative responses to qualitative changes in the environment and strategy. The learning approach of system dynamics is to use quantitative models and scenario runs, in order to explore, qualitatively, the behaviour of the system. Thus, it often suffices to show, with the help of a model, that barriers and optimal choices exist in order to improve discussions on strategic/tactic issues. Of practical importance are notions such as 'the optimal value for promotions shifts to the right (more promotions) when the total chain margin is increased'.

Creating a joint promotion budget

In this section, we calculate steady-state levels for the number of repeat (H) and occasional users (L), as given by equation 1d in Appendix 1. All other variables are computed according to the other algebraic functions.

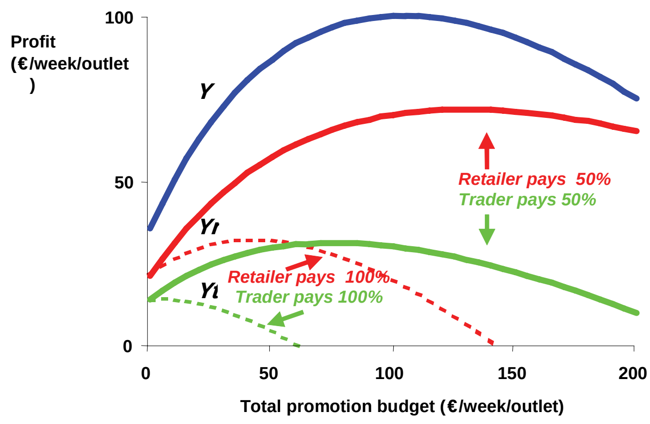

Figure 4*. Profits per chain player as function of the total promotion budget. Dashed lines indicate the profits – after the promotion cost – when the retailer or trader pays 100% of the promotion budget. Solid lines correspond to the profits when 50%/50% cost sharing of the promotion budget between retailer and trader is negotiated*

Figure 4 illustrates what the effect can be of cost sharing, in this case of the promotion activities. Promotions here denotes all activities that make consumers try the product (mathematically, move from the *N* to the *L* state). It may be giving away whole products to take home, have tasty pieces in the supermarket, advertising, etc. A simple free-rider problem exists, as promotions paid for by one player (e.g., the trader) automatically improve the profits of the other (the supermarket). In Figure 4, the dashed lines denote the profits, after deduction of the promotion budget of each player when they pay 100% of the promotion cost themselves. Without promotions, profits for the retailer (Y_r) and trader (Y_t) are 14 and 21 €/week, respectively, per supermarket store.

The pay-off for the trader is unattractive; his profits would only decrease at every non-zero promotion budget. For the retailer, the profits do increase somewhat, until a promotion budget of 45 €/week/outlet, but the profit gain, from 21 to 32 €/week is too small to bother, given that a supermarket has many other products to attend to, and can afford to be critical in directing scarce resources.

Interestingly, the picture changes strongly when the trader and the retailer agree to share the cost of promotion, at 50%/50% for example. The reason is that the promotion cost per product item is offset by the total chain margin, and not by the margin of one player only. The maximum values of the solid curves for the pay-offs (profits) for the trader, the retailer and the combined profits (upper line, indicated with Y_c) lie around three times as high as is the case without promotion. The locations of these maxima differ, with the trader expected to prefer a promotion budget of around 80 €/week/outlet, whereas the retailer, if it would dare to fully optimize profits, would go as far as 130 €/week/outlet. However, the chain profit is maximal at 100 €/week/outlet.

Which player profits from ready-to-eat positioning?

Suppose now that a joint promotion budget has been agreed between the retailer and the producer of 65 € per week per outlet, shared 50%/50% between them. We now look at the positioning of exotic fruits as ready-to-eat (close to T = 8) instead of selling them at an on average unripe stage (T = 5). As Figure 3 showed, the dilemma is in avoiding product loss while satisfying consumer preferences. Therefore, we focus on the cost-sharing parameter f_w that determines which party accepts the risk of product loss. In the left-hand panel of Figure 5, the profit for each player is shown as a function of the average batch ripeness (T), both for the situation where the retailer pays for product loss (f_w = 1, dashed curves) and where the trader will take back all unsold product without cost to the retailer (f_w = 0, solid curves). The incentives to reposition (increase) the ripeness of sold fruit and to reduce the variation within each batch change strongly depending on this parameter, which identifies the bearer of product-loss risk (the retailer if f_w = 1, the trader if f_w = 0).

If the retailer pays for all product, whether sold to consumers or lost on its shelves (f_w = 1, dashed curves), as is commonly the case with fresh produce, the trader sees profits rise whether the fruits are eaten or lost, and the trade-off between limiting product loss and complying to consumer preferences applies to the retailer only. The retailer would find an optimal ripeness of around T = 6.6 days, even though the total chain profit has an optimum at T = 7.2 days. Alternatively, the trader could offer during negotiations not to charge for the volume that is lost on the retailer's shelves due to the ready-to-eat positioning, reflected here as f_w = 0 (solid curves). In that case the incentives change considerably, and both players should be expected to give ready-to-eat positioning a try with optimal values of T between 7 and 8 days (8 days being the middle of the acceptance region of consumers, their 'favourite ripeness'). This arrangement alone would not make the trader make much more profit, but it changes also the incentive of another profit-enhancing innovation that would otherwise not occur: reducing the variation of ripeness of fruits within a batch (parameter *v*). The right panel shows how profits increase as this variation is decreased (e.g., from $v = 5$ to $v = 2$, read from right to left).

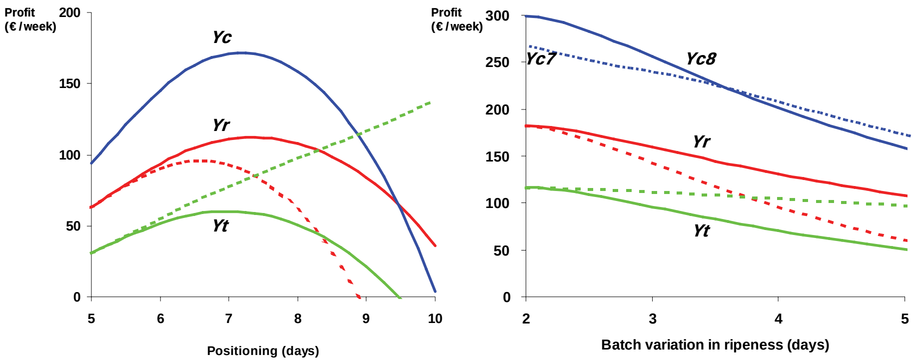

Figure 5*. Profits per chain player as function of the average ripeness (left) and variation in ripeness (right). Dashed curves indicate $f_w = 1$, solid curves $f_w = 0$. Left-hand panel is with variation v = 5 days, the right-hand panel is with average ripeness T = 8 days (except for dotted line indicated Yc7, which corresponds to T = 7)*

The dashed lines in the right hand panel represents the profits of the two players when the retailer bears the product-loss costs ($f_w = 1$), the solid lines denote $f_w = 0$. Again, a strong change in incentives occurs when the trader absorbs product-loss costs. The chain profit (sum of the profits of these two players) is denoted for both $T = 8$ (labelled *Yc8*) and for $T = 7$ (labelled *Yc7*), which allows to see that when the variation of ripeness is 'under control' ($v = 2$), the optimal positioning is again somewhat shifted towards the preference of consumers ($T = 8$), whereas with $v = 5$, at the far right of the right-hand graph, it would be better to stick to $T = 7$, as the variation is reducing profits through a large product-loss fraction.

The profits from optimizing product loss

Finally, we show how it is possible to determine the degree of product loss (W) that optimizes profit. In the left-hand panel of Figure 6, the chain profit *Yc* is shown as function of the product-loss fraction *W*, for four values of the variation in batch ripeness *v*. The right-hand panel first computes the positioning parameter *T* that results in the accepted product-loss fraction *W* on the x-axis. It results from solving equation 3 for *T* as a function of *W*. The profits are subsequently computed and plotted in the left-hand panel.

Although product loss can be seen as a consequence of product positioning on the ripeness dimension, as graphically shown in Figure 3, we may turn the argument in the opposite direction, in order to assess the optimal product positioning (shown to exist in Figure 5) as function of the product-loss fraction. We do this, because product loss may be easier to measure than consumer-preference parameters. The idea would be that the results in Figure 6 are more robust to uncertainty in estimates for parameter values than Figure 5. In Figure 6, the existence of an optimal level of product loss is shown (filled circles). At the same time, it demonstrates how this optimal level of product loss depends on variation control, and what the effect of reduced variation on profits is. As the variation is reduced from 5 to 2 days, profits increase and product loss decreases, even though the positioning (right-hand panel) is shifted towards riper fruits. Retailers can thus monitor product-loss fractions in relation to variation in ripeness, in order to adjust the ripening time of fruits in the supply chain, in order to optimize profits.

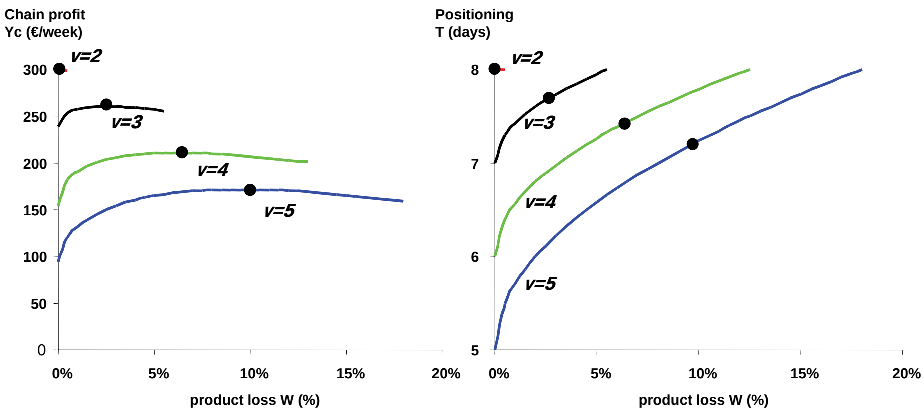

Figure 6. *Chain profit (Yc in Figure 5) as a function of product loss (W, given as percentage) is shown to have an optimum (●), dependent on the level of variation (v) of the quality attribute in the batches in the left-hand pane*

DISCUSSION

By combining product quality and its variation within batches of the product with the costs and benefits of different constituents in the production and supply chain of ready-to-eat exotic fruits and relating this to consumer behaviour, we make clear the peculiarity of highly perishable produce with biological variance. These types of chains occur mainly in the ready-to-eat food and ornamentals supply chains. From Figure 4 it is clear that vertical cooperation and risk/cost sharing can lead to simultaneous higher profits for different participants in these chains.

In this thought-experiment we use ‘ripeness’ to denote the apparently sole quality factor influencing consumer behaviour (aside from price, which is not varied in the model study for clarity’s sake). However, ‘ripeness’ is itself a composite of several product attributes (texture, sweetness, smell, etc), and it is in fact meant to denote the Principal Component of all quality attributes of the product under study. In this way it is meant as a generic term for ‘main axis of product quality’ that can be influenced by the supply chain. The model shows that the most likely positioning of the product (e.g. here in terms of fruit ripeness) depends strongly on which trade partner (the retailer or the trader) takes responsibility for the loss of product. If the retailer pays for product loss, he will tend to position the product at an unriper stage, and failing to match the Liking function of the consumer, and therefore reducing the profit for both retailer and trader. If the trader takes the responsibility for product loss, both retailer and trader will tend to extend the positioning date, enhancing the Liking function and thereby increasing profit for both of them. This is strongly dependent on the amount of variation in ripeness in the batches of product. Figure 5 shows that at minimal levels of variability in quality (v = 0), profits for all parties are highest, but also that the profit difference between the cases where either the downstream or the upstream party takes responsibility for the product loss vanishes. This makes clear why these advantages of vertical cooperation in chains are not so clear in non-food chains, where variations in product quality within batches of the same product are usually negligible.

The model indicates that product loss due to over-ripeness in the retail should *still* be accepted, and even optimized. This approach is different from the classical approach in logistics where product loss *per se* is taken as the most critical factor and is minimized at all times. This is due to the fact that consumer behaviour is not included in these logistical calculations. However, it is clear from our model that a certain amount of product loss comes with an optimal positioning of ready-to-eat food in order to obtain the highest profit possible under the circumstances. Let us try to explain this: at present many exotic fruits are harvested at an unripe stage to allow long-term transport to distant outlets. If the fruits become ripe too early they usually start producing volatile plant hormones such as ethene (ethylene). These gasses tend to trigger autocatalytic ripening processes in nearby fruits. As such, whole cargoes of fruits can be destroyed en route. As a consequence the fruits generally do not reach the proper ripening stage even when the consumer buys them and the consumer will be disappointed in the taste of the fruit. If the vertical participants in the chain were to cooperate on the level of fruit ripeness and variation in this ripeness factor, the optimal profit for all partners in the chain could be elevated and the consumer would be more satisfied with the product. The model shows the advantage all participants in the chain can obtain from this cooperation and as such can be used as a tool to support negotiations between potential chain partners to the benefit of all chain participants. The model shows that classical supply-chain management approaches, focused on limiting product loss, yield a sub-optimal profit level. The modelling exercise makes it clearer how making consumer preferences the leading factor behind product revenues, further increases total chain profits. It is therefore meant as a main step towards consumer-driven product development.

Obviously, further research is necessary, especially in the area of calibration and validation. A large agenda for further research has been drawn up, as the current model can function as a backbone of tying the different disciplines together. Addressing the more specific dynamics of fruit ripening and its effect on keeping quality and product loss is our next step. With mango for instance, it is suspected that mangoes harvested before a critical ripeness, will never ripen properly while in the supply chain. The fruit will deteriorate earlier. How these effects work out for various fruits and are affected by the variance in ripeness within batches is critical (see Tijskens and Polderdijk (1996) and Tijskens et al. (2003)). When these issues have been addressed to some degree of detail, heuristics may be derived that can guide practical implementation of fresh exotic-fruit chains.

REFERENCES

Schepers, H.E., Van Henten, E.J., Bontsema, J., et al., 2004. Tactics of quality management and promotions: winning consumers for fresh exotic produce. *In:* Bremmers, H.J., Omta, S.W.F., Trienekens, J.H., et al. eds. *Dynamics in chains and networks: proceedings of the sixth international conference on chain and network management in agribusiness and the food industry (Ede, 27-28 May 2004)*. Wageningen Academic Press, Wageningen, 568-582.

Sterman, J.D., 2000. *Business dynamics: systems thinking and modelling for a complex world*. McGraw-Hill, New York.

Tijskens, L.M.M., Konopacki, P. and Simcic, M., 2003. Biological variance, burden or benefit? *Postharvest Biology and Technology,* 27 (1), 15-25.

Tijskens, L.M.M. and Polderdijk, J.J., 1996. A generic model for keeping quality of vegetable produce during storage and distribution. *Agricultural Systems,* 51 (4), 431-452.

APPENDIX 1: MODEL EQUATIONS

The dynamics of the number of repeat users (*H*). occasional users (*L*) and non-users (*N*) is described by the following differential equations:

$$\frac{dH}{dt} = QE_Q L - H/\tau_H \tag{1a}$$

$$\frac{dL}{dt} = -(QE_Q L - H/\tau_H) + (UE_U + r_L)N - L/\tau_L \tag{1b}$$

$$N(t) = Z - L(t) - H(t) \tag{1c}$$

where $Z = N + L + H$ is the total number of consumers. Product quality Q and promotions budget U (see Table 1 for units) are the management levers that determine the size of the consumer segments. E_U is the promotion effectiveness, and r_L is the spontaneous rate of trying the product. Solving equation (1a-c) gives the steady-state solution

$$\frac{L}{Z} = \frac{1}{1 + \left[(r_L + UE_U)\tau_L\right]^{-1} + QE_Q\tau_H} \tag{1d}$$

from which the steady-state values for *H* and *N* are found easily. The product quality *Q* is the integral from the minimum acceptance level (*a*) to the maximally accepted perceived ripeness (*m*) of the variation distribution of supplied fruit ripeness represented by the piecewise 'tent' function, the horizontally hatched area in Figure 3a:

$$\begin{cases} Q = 1/2\left(\dfrac{T+v+a}{v}\right)^2 - 1/2\left(\dfrac{T+v-m}{v}\right)^2, a > T \\ Q = 1 - 1/2\left(\dfrac{T+v-m}{v}\right)^2 - 1/2\left(\dfrac{v+a-T}{v}\right)^2, a < T \end{cases} \tag{2}$$

Finally, W is the product-loss percentage due to unacceptable fruit, v being the variation within each batch of fruit with respect to firmness (in days), and m is the maximum firmness limit (too soft) that consumers accept. It determines the point where product loss starts. W is the vertically hatched area in Figure 3 (left-hand panel), and its expression is

$$W = 1/2\left(\frac{T + v - m}{v}\right)^2 \tag{3}$$

for $T+v>m$ and otherwise zero.

The outputs of the model are the profit levels of the chain players, Y_r for the retailer, Y_t for the trader and Y_p for the producer. The profit of the retailer is calculated as the product of sold volume and gross margin, minus share of promotion cost. The volume V bought by consumers equals

$$V = (D_H H + D_L L)d^e \tag{4}$$

where D_H and D_L are the intended usage frequencies for fruit for H and L, respectively (for values and dimensions see Table 1 below), d (dimensionless) is the relative price position taken by the retailer, and e is the price elasticity of consumers (all segment being equal in this respect). The profit of the retailer is found after multiplication by the retailer gross margin (in square brackets) and subtracting its share of promotion cost (which is here the only product-related fixed cost considered):

$$Y_r = V\left[dP_{cr} - \frac{P_{rt}}{1 - f_w W} - \frac{C_{hp} + TC_{hd}}{1 - W}\right] - (1 - u_t)U \tag{5}$$

where P_{cr} is the consumer reference (expected) price, P_{rt} is the ‘transfer price’ or purchase price between the retailer and the trader, C_{hp} is the fixed handling cost per piece of fruit by the retailer, C_{hd} is the handling cost per piece per day that the retailer has the fruit in storage, before display on store shelves. The fraction of the product-loss volume that the retailer has to pay for to the trader, f_w, thus only affects the purchased volume, not the cost of the handled volume. Finally, u_t is the share (percentage) of promotion cost that the trader pays. The profit of the trader follows as

$$Y_t = \frac{V}{1 - f_w W} P_{rt} - \frac{V}{1 - W} P_{tp} - u_t U \tag{6}$$

where the volume sold to the retailer is adjusted for the product-loss fraction f_w , whereas all volume, whether bought by consumer or wasted at the retailer, has been paid to the producer/exporter. P_{tp} is the transfer price between exporter and trader.
The profit of the producer has the expression:

$$Y_p = \frac{V}{1 - W} [P_{tp} - C_p] \tag{7}$$

with C_p being the unit cost to the exporter. Adding up the profits of the trader and retailer, the 'marketing chain', the chain profit Y_c becomes

$$Y_c = V \left[dP_{cr} - \frac{C_{hp} + TC_{hd} - P_{tp}}{1 - W} \right] - U \tag{8}$$

and is, as expected, independent of the cost-sharing parameters f_w, u_t and the transfer price P_{rt}.