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Modeling Value of Natural Food Preservative Using an Example of Innovative Chitosan Orange Peel Complex

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***Abstract*—The increasing awareness of the health hazards assisted with preservatives used in today's foods draws great attention to the complete food manufacturing chain.**

Research presented in this paper based on the author's successful development of the innovative natural food preservative applied in a meat product and the subsequent evaluation of its production in business models.

The modeling of different quantities of both: currently used, nitrite based preservatives, and the developed chitosan orange peel complex, exposes slightly higher costs of the later one, as compared to nitrite based preservatives. The production ramp-up in Switzerland, Poland, Thailand and China differentiate by less than 20%, leaving room for the inclusion of intangible aspects in the final choice of the manufacturing location.

***Keywords*—business modeling; natural food; organic food; additive preservatives; coating preservatives**

I. Introduction

Today preservation methods have been modernized not only to meet desire of food producers but also to maintain food quality and safety in different products. The promising techniques of food preservation, e.g. modified atmosphere packaging, carbon dioxide enrichment, addition of weak acids, food irradiation, high hydrostatic pressure (Pascalization), non-thermal pasteurization, pulsed electric field processing (PEF treatment), addition of chemical preservatives such as sodium nitrite, potassium nitrate which are most commonly applied as preservatives in meat products.

High heat cooking may form hazardous nitrosamines which considered one of the cancer causes. Roger et al., demonstrated that daily consumption of nitrite-containing meats may be associated with an increased risk of esophageal cancer [1]. Zheng et al., in a study of oral cancer in Shanghai, found an increased risk of oral cancer in individuals who consumed higher quantities of salted meat and fish [2]. European Food Safety Authority EFSA set the daily acceptable limit of intakes (ADI) for nitrate at 3.7 mg/kg body weight. This is easily and severely exceeded particularly by the elderly and the financially weaker group who tend to consume higher frequency of preserved foods [3].

The health hazards associated with synthetic preservatives provoke awareness and interest of the society into natural antimicrobial and antioxidant preservation. Sales of organic food between 1999 and 2016 have risen six folds to 90 billion US$ [4]. The health and wellness products have been experiencing a continuous growth of 11%. Furthermore, products made of fresh natural or organic ingredients are ranked second and third most sustainable purchasing drivers [5]. 2018, Swiss turned out to be the worldwide highest spending on organic products per capita accounted for US$ 332/ person/year [6]. This turned out the interest of science and business towards natural food preservation.

The next chapter presents the state-of-the-art concerning the science of natural food preservation, followed by a short overview of the methods, used in the presented research. The coming chapters present the laboratory-performed development of an innovative chitosan orange peel complex preservative following by business models of large scale manufacturing of the complex varying different geographical placements of the factories in Switzerland, Poland, Thailand and China. Impacts of production volume also included in the conclusions.

II. Literature Survey

The food industry has been playing a central role in the European Union [7]. During the last decade, customer needs have changed dramatically, instead of consuming food only to fulfill hunger, but rather to improve physical and mental well-being [8]. As a result, the implementation of innovation in food developing segment has been one of the key strategies to develop a product that satisfies customer demand [9].

A research survey of the customer making purchasing decisions has carried out that, consumers ranked both the ingredients list (77%) and clean label positioning such as natural or no additives/preservatives (68%) above nutritional information (59%) and brand (53%). What is more, the global clean label ingredient market is expected to value USD 47.50 billion by 2023 due to customer demand for natural ingredients [10]. Manufacturers, therefore, need to ensure a full understanding of what really drives customer purchasing decisions [11].

The phenolic compounds may be found among natural sources such as vegetables, seeds, cereals, berries, wine, tea, onion bulbs, olive oil and aromatic plants [12]. This indicates the effective activities that limit lipid oxidation and extend shelf-life in food products [13,14,15]. However, taking advantage of by-product from industrial production have gained more interest not only to lower the cost but also to improve waste management issue [16]. Mehdizadeh and Langrood proved that chitosan in various combinations, in particular with propolis impacts positively the microbial and regard the oxidative activity in chicken meat [17]. Wang et al. applied grapefruit seed extract-loaded (e-caprolactone)/chitosan films [18], whereas Merlo et al. incorporated successfully pepper residue extract into chitosan films for antimicrobial food packaging [19]. Similarly Wang et al. applied it successfully in preservation of sausages [20], Sun et al. proved, that MRP-treated chitosan exhibits strong antibacterial activity prolonging the shelf life of lamb meat by more than two weeks [21]. We conclude that chitosan complex in general bear the business potential, further evaluated in this paper.

III. Selected Methodological Approach

Justified by the proved scientific results of the hazards related to current preservatives. The research questions focus on the exemplification of "What?" and "How?" without the claim of completeness [22].

The SLR had been conducted taking the following criteria under considerations:

- Natural and organic food as antimicrobial agents
- Natural and organic food preservatives
- Chitosan health impact and processing
- Orange peel antimicrobial effects
- Chitosan orange peel complex
- Natural food preservatives business models

The contents are considered rather by the intended message than the pure semantics. Based on the theoretical background, the experimental research was performed in the laboratory to find out and prove the feasibility of the innovative chitosan orange peel complex based preservatives [23].

The technological steps, conceived after successful laboratory tests, have been subsequently mapped onto the feasible industrial large scale production facilities using the innovation management techniques [24]. The geographical, financial and enterprise risks were taken into accounts [25,26] as well as the global chain concepts [27].

Business models are elaborated using International Accounting Standards [28] Business Model Framework BMF of Chesbrought [29] and entrepreneurial plan of Kuratko [30].

Regarding cost calculations, the unit cost of a product was applied [31]. The machines, labor and energy costs have been either taken from published datasheets or estimated, basing on the technological knowledge of the author.

In the approximation of the production purposefulness, the break-even analysis has been used [32]. The exemplary price impacts on sample sausages were well balanced again the esteem value [33] of natural food.

IV. Production Modeling Of Chitosan Orange Peel Complex

World production of citrus fruit has experienced continuous growth in the last decades of the 20 century. Orange juice received the largest volume of shares among all other drinks [34]. 50% in juice production is peel, by-product, deposited as waste to feed the cattle, produce biogas or simply burned down (with malicious CO2 release) [35, 36]. Same time, orange peel exposes several proven vital positive factors e.g. anti-cancer, anti-inflammatory, antioxidant and antimicrobial (for details see [23]).

Encapsulation technology was efficiently applied to develop the innovative preservation from wasted orange peel. Additionally, chitosan has been used as part of encapsulating components. It exposes the antioxidant capacity, antibacterial properties, positive cationic polyelectrolyte and what is attractive to many: is a proven fat binder [37]. It is used in 45% in water treatment and in only about 20% in food and beverage manufacturing [38]. With the projected almost six fold market potential 2019-2025 in USA only, the supply of chitosan is sustainably secured [ditto]. Currently, the biggest manufacturer of Chitosan is China [39]. Chitosan has found its way to the inventory of the European Union Food and Agriculture Organization of the United Nations (FAO) as well as World Health Organization (WHO) Committee [40] and in a volume of 3 g ADI was approved by the EU Commission Regulation 432/2012 [41].

Now under specific environmental conditions, indicated in Fig. 1, orange peel extract got encapsulated by chitosan producing a complex (Fig. 2) with proven phenolic compound, antioxidant properties and most of all: antimicrobial properties against *Echerichia coli*, *Stapholycoccus aureus* and *Salmonella enterica subap.*

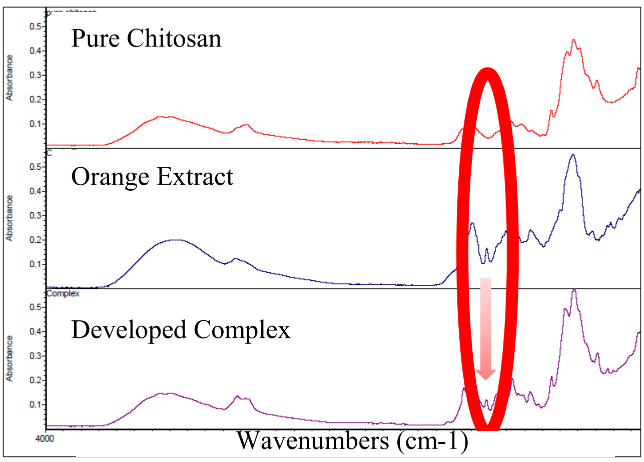

Fig. 1. Fourier transform infrared spectroscopy (FTIR) spectrum of complex

Fig. 2. Chitosan orange peel complex

The application of the developed complex in experimental chicken sausage coating exposed: lower ThioBarbituric Acid number (TBA, lower fat oxidation rancidity even after 21 days of shelf life, increased shelf life to 24-27 days, as compared to 12-15 days of uncoated sausage, higher hardness, better water holding capacity, lower drip loss with same time undistinguishable color, smell and taste [23].

The lean innovation process (Fig. 3) included pre-production intense cytotoxicity testing, digestion modeling as well as the parallel marketing process. The production facilities comprise washing line, blending machine, agitator mixer tank, evaporator, mixing tank, freeze dryer and freezer storage room. In coating use additionally the agitator mixer tank, coating machine and hot air oven are needed.

They are sized to produce 40’000 kg per year in 2 shifts, 5 days a week delivering preservatives for a medium-sized 100’000 tons meat products/year company.

The estimated fixed and variable costs for a start-up company are summarized in Table I.

Whereas as expected the machine costs are location independent, the variable costs, like labor, raw material transport and energy impact the net costs of the complex by about 20%. Leading is China, which manufactures all components of raw materials thus reducing the transportation costs with still reasonably low cost labor. The manufacturing costs have to be matched against the intangible values like quality, dependability, political stability and sustainability of deliveries.

V. Business Modeling Of Preservative Production

With a yearly 10% of investments amortization and 90 CHF/kg is expected selling price, the break even for complex as the additive is reached already at less than 4000 kg of complex (means within 1 month of full production capacity, longer for gradual production increase, see Fig. 4.).

As can be seen in Fig. 4 at the assumed production costs and 10 years amortization of the production facilities break even is highly sensitive to variable volume costs. The minimum production shall not fall below 4000 kg per year.

In the application of complex as a preservative, the amount of about 8 grams is needed irrespectively of the size, weight and packaging of the final product.

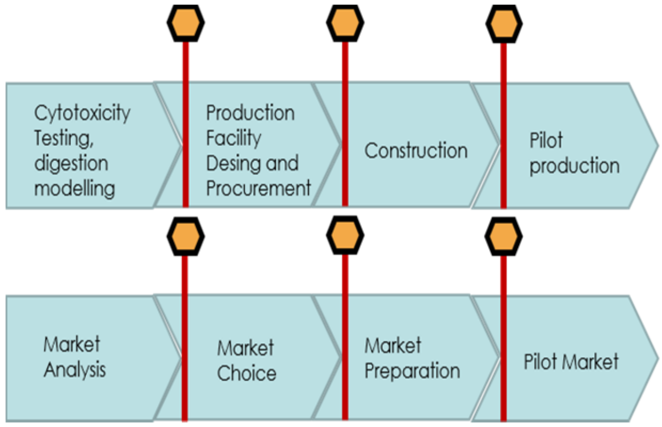

Fig. 3. ultural impact on affection.

TABLE I. Fixed And Variable Production Costs

Factors	Unit	Switzerland	Poland	Thailand	China
Machines & equipment	CHF	445'000	445'000	445'000	445'000
Coating equipment	CHF	35'000	35'000	35'000	35'000
		Factory construction			
Design	CHF	100'000	100'000	100'000	100'000
Delivery and Installations	CHF	150'000	150'000	150'000	150'000
Test	CHF	150'000	120'000	100'000	100'000
		R&D			
Production process devel.	CHF	70'000	60'000	50'000	60'000
Health & safety test	CHF	30'000	25'000	20'000	20'000
Management Fee	CHF	150'000	110'000	90'000	100'000
Total Investment	CHF	1’095’000	1'010'000	955'000	975'000
		Complex Cost			
Raw mater. (Production)	CHF/kg	66.04	64.2	61.6	59.39
Expenses (Var. cost)	CHF/kg	13.85	7.76	5.95	5.95
Expenses coat. (Var.)	CHF/kg	1.19	0.68	0.52	0.6
Net cost of complex add	CHF/kg	**79.89**	**71.96**	**67.55**	**65.87**
Net cost of complex coat	CHF/kg	**81.08**	**72.64**	**68.07**	**66.47**

It looks different if applied as a coating. Taking exemplary sausages. 4 pieces about 12cm long, and 1.5 cm in diameter, 200 grams in total, we have about 51 cm2 of the surface to cover with the complex solution. This leads to a higher quantity of about 1.5 g of the complex used in the slightly more expensive process of additional coating, making it twice as expensive in this case. Fig. 5 illustrates the differences.

With an esteemed value of e.g. 10% over the current price (lowest at 3.00 CHF) the cost of a change to a definitely healthier natural food preservatives are more than compensated (at least 300% of production costs).

VI. CONCLUSIONS

Chitosan-Orange peel complex presents preferable laboratory results as a food preservative. As a food preservative, it may be applied directly into the food or as a coating agent.

Current customer trends favor the natural food components, in particular as a substitution. The esteem value of 10% covers the costs of complex production and use with a high margin of 200% for any non-production costs (like e.g. marketing).

The conservative business plan and available competences open new business opportunities and market leadership in healthy food production for an innovative food manufacturer.

The price difference in the manufacturing of a complex is within 20% margin. The lower labor costs in Thailand may be compensated by the overall lower productivity as compared to other countries. China with salaries rising 10% per year and average workforce employment of 2 years at one place impose certain risks. The prohibitively high prices of energy in Poland lower the country competitiveness. The high transport costs for both Poland and Switzerland are unavoidable.

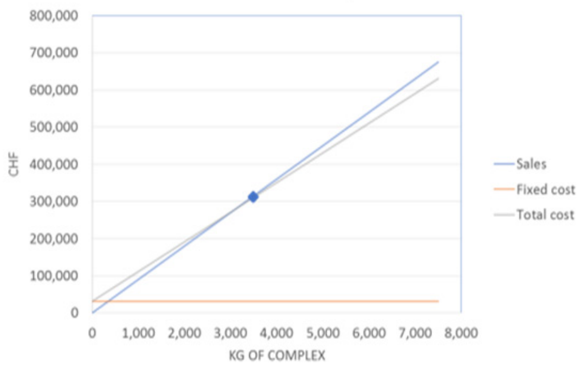

Fig. 4. Contribution Break-even chart calculated based on manufacturing of complex in Switzerland.

Fig. 5. Complex as an additive or coating preservative Swiss start-up.

So in the final decision about the location of the company shall be taken beside the economical calculations also the intangible effects, like those, mentioned above.

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