Substitution Potential of Bio-Based Packaging Films in Food Industries

Substitutionspotenziale biobasierter Hemizellulose-Folien in der Lebensmittelindustrie

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Summary

Hemicelluloses based films (HBF) may be used for food packaging. Based on information from a B2B-survey in the food packaging industry in German speaking countries, a substitution potential model considering varying film properties was developed. State of the art HBF show therefore a potential of 927 t/a or 0.1% of the total volume. The high water vapor permeability and the lack of sealing capabilities are considered major limitations.
Keywords: food packaging, substitution potential, hemicellulose, innovation management

Zusammenfassung

Hemizellulose basierte Verpackungsfolien (HBF) können unter anderem als Lebensmittelverpackung eingesetzt werden. Auf Basis einer B2B-Befragung wurde ein Substitutionsmodel unter Berücksichtigung der technischen Eigenschaften entwickelt. Demnach kommen bestehende HBF auf ein Potenzial von rund 927 t/a oder 0,1% der eingesetzten Menge im deutschsprachigen Raum. Die hohe Wasserdampfdurchlässigkeit und die mangelnde Siegelbarkeit sind dabei die limitierenden Faktoren.
Schlagworte: Lebensmittelverpackung, Substitutionspotenzial, Hemizellulose, Innovationsmanagement

Erschienen im *Jahrbuch der Österreichischen Gesellschaft für Agrarökonomie,* Band 24: 161-170, Jahr 2015. On-line verfügbar: http://oega.boku.ac.at.

1. Introduction

Recognizing the limited availability of fossil resources many industries are increasingly take into account sustainable materials for packaging (HANSEN and PLACKETT, 2008). Bio-based films such as made from hemicelluloses, could become an efficient means for packaging based on renewable resources (KAMM and KAMM, 2004). Hemicelluloses are plant polysaccharides that can be frequently extracted from agricultural wastes or wood residues as for example in biorefineries. According to PÉROVAL et al. (2002) they have comparable mechanical properties comparable to cellophane films. Although this implies that HBF could be used in similar applications like cellophane these films face the disadvantage of lacking sealability. However, the combination of adequate mechanical properties with the excellent barrier properties makes HBF attractive for the food industry (HÖIJE et al., 2008). Various HBF with such properties have been developed by MIKKONEN et al. (2010), GRÖNDAHL et al. (2004), HÖIJE et al. (2008) and WILLFÖR et al. (2008) and many more. It is mainly the oxygen barrier that creates the interest as the detoriation of unsaturated fatty acids is depending on oxygen availability (MIKKONEN et al., 2010).
The aim of this study was to verify and quantify the impacts of various film properties from literature on the application within food packaging.

2. Methods

The following variable factors influencing the substitution potential in size were identified based on literature (NENTWIG, 2006):

- Oxygen barrier (HARTMAN et al., 2006),
- Water vapor permeability (HARTMAN et al., 2006),
- Sealability (CARLOWITZ, 1995),
- Storeability (MIKKONEN, 2009),
- The requirements in context to the variable factors specified above are assumed to depend on the nature of the food packed (OLBRICH, 2006). Hence, food packaging was divided into eight application fields: Meat and sausages,
- Cheese and dairy products,
- Bakery products,

- Pasta and dried foods,
- Fruits and vegetables,
- Confectionary,
- Convenience,
- Beverages.

The following requirements for each of these fields were investigated within a B2B-survey among food packaging companies:

- application specific optimum requirement on oxygen permeability (OP) in $cm^3 \cdot \mu m/m^2 \cdot 24h.kPa$,
- application specific optimum requirement on water vapor permeability (WVP) in $g/m^2 \cdot 24h$,
- percentage share of films used in this application with HBF specific low OP,
- percentage share of films used in this application with HBF specific low WVP,
- percentage share of films with sealability used in this application
- basic requirement on the storability (in months).

A total of 177 relevant companies were identified in the survey region (Germany, Austria and Switzerland). Hence, data was finally taken from 26 companies processing about 786,751 tons of packaging films a year. The companies originated from Germany (13), Austria (9) and Switzerland (4). Unfortunately three of the companies were not able or willing to provide basic information on the processed volumes. In these cases it was possible to estimate their volumes in relation to other companies of comparable structure and size in terms of turn-over, employees and share of food packaging in the companies operation.
Basically the substitution potential (SP) can be approximately seen as the multiplied percentage shares of the four variable factors.
Hence,
SP = % lowOP * % lowWVP * (1 - % sealed)
-> if storability is not less than basic requirement on the storability otherwise, SP = 0
This calculation approach assumes that the share of requirements regarding lowOP, lowWVP and sealability is always equal overall quantities. Although this may not always be the case this assumption is a simplification to keep the needed information as low as possible in order not overcharge the person providing the data. Furthermore this

approach allows assessing the opportunities for improved HBF.

Tab. 1: Base values for the OP and WVP of packaging films in the survey

	Oxygen permeability (cm³·µm/m²·24h.kPa)	**Water vapor permeability (g/m²·24h)**
Very low	0.3	0.3
Low	1	1
Medium	5	3
High	10	6
Very high	>10	>6

Source: DOMININGHAUS, 2005, 387ff; SCHRÖDER, 2009,18

3. Results

Referring to the year 2010 the responding companies stated a total sales volume of 786,751 tons of food packing films. A more differentiated analysis of the sales volumes can be done regarding the sort of the packed products (see Figure 1). It shows that most of the sales volumes are used for pasta and dried foods, followed by convenience.

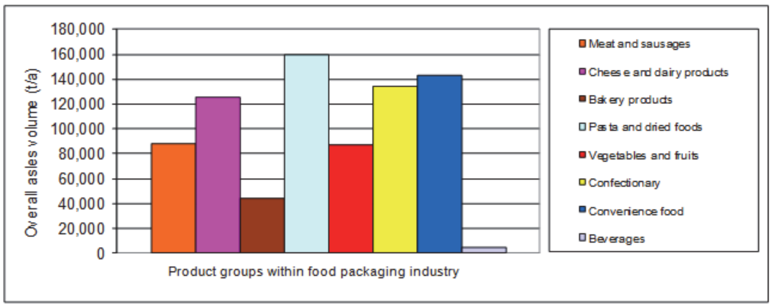

Fig. 1: Sales volume of packaging films by product category of all responding companies

Source: OWN SURVEY, 2014

The company representatives were asked in the interviews what they would consider as optimum requirements for the different product groups (see table 1). In order to receive a more precise picture the respondents were asked to indicate how much of the packaging in each product category is covered by films with the announced properties.

Tab. 2: Optimum oxygen and water vapour permeabilities of food packaging films in eight different product categories (n=26)

Product Category	**Oxygen permeability ($cm^3 \cdot \mu m/m^2 \cdot 24h.kPa$)**	**Water vapor permeability ($g/m^2 \cdot 24h$)**
Meat and sausage	1.00	3.00
Cheese and dairy products	10.00	6.00
Bakery products	5.00	3.00
Pasta and dried food	5.00	1.00
Fruits and vegetables	10.00	6.00
Confectionary	1.00	1.00
Convenience food	1.00	3.00
Beverages	n/a	n/a

Source: OWN SURVEY, 2014

As shown in table 2 the required OP is a minimum requirement in case of meat products, confectionary and convenience food whereas in cheese and dairy products the announced value is needed in 58% of the cases only.

Tab. 3: Property requirements for food packaging films in percent

Product Category	**Low OP (%)**	**Low WVP (%)**	**Sealability (%)**	**Shelf life (months)**
Meat and sausage	100	98	96	6
Cheese & dairy products	58	66	99	6
Bakery products	83	86	92	19
Pasta and dried food	83	100	100	25
Fruits and vegetables	0	12	100	6
Confectionary	100	100	85	24
Convenience food	100	98	82	6
Beverages	n/a	n/a	100	24

Source: OWN SURVEY, 2014

In addition to WVP and OP table 3 also shows the importance of film sealability and the required maximum shelf life for each of the applicable product categories.

In order to provide a positive but realistic example we decided to create a best available virtual hemicelluloses-based film (EB-50) based on references in the literature (e.g. MIKKONEN et al., 2008; PÉROVAL et al., 2002; TENKANEN et al., 2007; HÖIJE et al., 2008; MIKKONEN et al., 2010). We choose a 50µm thick HBF that provides an Oxygen permeability of $0.3cm^3{\cdot}\mu m/m^2{\cdot}24h\ kPa$ and WVP of $2g/m^2\ 24h$. This film could be stored for six months but would not be sealable.

Tab. 4: Substitution potential for HBF EB-50

Product Category	**Substitution Potential in %**	**Substitution Potential in volume (t/a)**
Meat and sausage	0,094	82
Cheese & dairy products	0,221	278
Bakery products	0,000	0
Pasta and dried food	0,000	0
Fruits and vegetables	0,000	0
Confectionary	0,000	0
Convenience food	0,396	567
Beverages	0,000	0
Total substitution potential	0,118	927

Source: OWN CALCULATION, 2014

Table 4 shows that such a film would be able to achieve a maximum substitution potential of 927 tons a year for the 26 interviewed companies. Based on the results above, it is possible to assess the implications of possible improvements and new technical developments regarding HBF. First of all sealability is a film property to be developed with HBF in the future the substitution potential would be increased by 32-times from 927t/a to 30,328t/a. After adding the sealability to the EB-50 fruit and vegetable packaging would be a suitable application if the oxygen barrier property of HBF would be lowered by perforation. Therefore additional 77.038t/a would become available for potential substitution at the 26 companies involved. Similar to the sealability an improvement regarding a lower WVP towards $1g/m^2{\cdot}24h$ could increase the substitution potential by 28.962t/a. The increase would be mainly achieved in meat and sausage packaging and in convenience food packaging.

4. Conclusion and Discussion

Up to day the lacking sealability and the high WVP are the major barriers for a larger scale introduction of HBF in the food packaging sector. Convenience food, cheese and dairy products as well as meat and sausage packaging are the three most promising product categories for HBF. This approach was limited to four properties selected from literature and confirmed by the responding companies. Although these four properties are definitely of great importance other properties could have been considered as well and may have influenced the results in a significant way. A major variable left out of these considerations was the price of the packaging film. This exclusion followed the idea that the results should be interpreted as a substitution potential that could be acquired under the assumption of providing a biodegradable packaging film for at least the same price of a conventional packaging film. This approach provides mainly two advantages one theoretical and one practical.

Theoretically the idea of introducing renewable resource based films follows the expectation of crude oil shortages and hence rising oil prices. As the conventional packaging films are of petrochemical origin rising or at least fluctuating prices for these films in the future are a major expectation. The inclusion of a fixed price or price differential between HBF and conventional packaging films would lead to a static assessment restricted to the present situation. Considering HBF as a matter of current research and development such an assessment would be of very limited benefit.

Practically prices of commodity products in a business to business environment are very difficult to assess. First of all the prices will depend very much on the contracted quantity. Larger quantities receive much lower prices. An adjustment to a standard quantity is very difficult if not impossible to proceed. Secondly companies to not like to give information about such prices which often leads to incomplete interviews or vague information.

The major advantage of the provided approach is of course the ability to assess possible impacts of technical improvements which is of great value in case of new technologies and products that are still in the process of development. Major assumptions are made when linking properties with processed quantities which influence the exactness and confidence of the gained results. The relationship between each property and the processed quantity needed to be simplified. In some cases like the minimum shelf life (always a knockout relation) or the sealability (given or not given) this could be done quite easy and without major information loss. In other cases as WVP and OP such relations are more complex as the quantity increases or decreases in a most likely non-linear manner. This linkage was based on the simplifying assumption of equal requirements in each subgroup as descripted in the methods section.

The approach can be of advantage in all cases assessing a substitution potential for a product or technology under development.

Acknowledgment

The research leading to these results has been received funding from the European Community's Seventh Framework Programme FP7/2007-2013 under grant agreement no CP-IP 228589-2 AFORE and the Austrian Federal Ministry of Science and Research under grant agreement 651.432/0001-II/2/2009.

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