Optimizing Quality Losses and Shelf-life in Bakery products by Edible coatings

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1. State-of-Art

Bakery products have complex textural properties; biscuits, cookies and crackers with low water activity have crispy texture as the main quality attribute for which high humidity causes softening, whereas, bread, cake, muffins with relatively high water activity tend to lose moisture and turn stale. Staling is predominantly due to retro-gradation of starch and is accelerated by moisture loss. Studies show that these textural changes can be reduced by edible films and coatings. Baeva & Panchev (2005) studied the effects of pectin based films on crumb ageing of sucrose free dietetic sponge cake which results in loss of mouth feel, texture; softness and increases dryness. The pectin films were observed to retain the freshness of the sponge cake. Similarly, Bartolozzo et al., (2016) observed that triticale flour based coatings preserved the muffins freshness by retarding the process of crumb firming. Another study on dry bakery products by Bravin et al., (2006) concluded decrease in moisture uptake in crackers when coating is applied. Ferreira Saraiva et al., 2016, studied the effect of active edible coatings made from potato starch on the shelf life of Mini-panettone. The results show that both edible coatings with and without active ingredient had a preserving effect on the mini-panettone, in terms of texture, moisture content and microbial counts and was observed to increase the overall shelf-life.

Available studies discuss the study of textural effects and moisture loss during staling of bakery products when applied with coating. This necessitates to preliminarily understand the effect of application technique and stage of application on coating uniformity and bakery texture. Once, the application technique is standardized the coatings can be exploited to evaluate their retaining effect on different bakery goods with different water activity levels. Moreover, the coatings can be prepared to alter the incidence of rancidity by use of anti-oxidant coating and anti-microbial coating to extend the shelf-life by reducing the incidence of microbial growth. The efficacy of edible coatings also for protective additional effect will be further tested on the products packed with different materials.

2. Bibliography

Baeva M, Panchev I (2005) Investigation of the retaining effect of a pectin-containing edible film upon the crumb ageing of dietetic sucrose-free sponge cake, Food Chem, 92: 343–348.

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Ferreira Saraiva LE, Naponucena L de OM, da Silva Santos V, Silva RPD, de Souza CO, Evelyn Gomes Lima Souza I, Druzian JI (2016) Development and application of edible film of active potato starch to extend mini panettone shelf life, LWT-Food Sci Tech, 73: 311–319.

2. Objectives and Milestones

The activities within the objectives of the research project can be divided as summarized in Gantt chart (table 1):

1) Bibliographic research on edible coatings and their use in food products, in particular, bakery goods. Train in basic laboratory activities and plan the experiment.
2) Development, characterization and application of edible coatings and films and select technique of application- spraying, spreading or dipping on bakery product (bread).
3) Preparation and analysis of coated bakery product (bread) for physico-chemical parameters during storage – evaluation of drying time (A 3.1) and effect of coating during storage (A 3.2); Effect of application stage and type of coating (A3.3)
4) Evaluate the efficacy of active edible coatings on preserving the quality of bakery products (bread)

Table 1. Gantt Chart for the research activities in scope of doctoral study

Activities		Month																	
		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36
A1)	***Research review and Training***																		
	Literature review																		
	Lab training & experiment design																		
A2)	***Evaluation of Application techniques***																		
	1) Development and characterization of edible coatings and films																		
	2) Selection of edible coating																		
A3)	***Analysis & shelf life studies***																		
	1) Evaluation of drying time																		
	2) Storage of coated samples & shelf life evaluation																		
	3) Application stage and type of coating																		
A4)	***Active coatings***																		
	1) Development and evaluation of active coatings																		
A5)	***Thesis & scientific paper preparation***																		

4. Progress of research and main results

This research project aims to evaluate the effectiveness of edible coatings on the quality and shelf-life of different bakery products. The main objectives of this project are to (i) study edible coatings and films in particular for bakery applications and (ii) understand effects of coatings on physico-chemical, mechanical properties during storage with an aim to reduce packaging impact.

A2.1 Development and characterization of edible coatings and films: The edible film forming solutions and films were evaluated for physico-chemical, mechanical and thermal characteristics. The interaction of whey protein concentrate with Pectin and Alginate was observed to lower the viscosity and increased the elasticity of the films. Also, a significant ($p<0.05$) positive effect on the hydrophobicity, gas barrier properties and thermal stability of the films was observed. These preliminary findings show that the tested multi-component coating or films can be used as such or improved with hydrophobic or active compounds for applications in food.

A2.2 Selection of edible coating: As a potential matrix to decrease the quality changes in bakery product (bread), it is necessary to understand the possible application techniques and effects on preliminary properties like moisture and texture. To optimize, trials to moderate the viscosity of coating with regard to weight of coating and spreadability was carried out and the coating solution viscosity was altered by increasing the total biopolymer content from 3.0% (pH - 4.8± 0.01, TSS – 3.4 ± 0.06, aw – 0.98 ±0.001) to 4.5% (pH - 4.7± 0.01, TSS – 5.4 ± 0.06, aw – 0.97 ±0.001).

A 3.1 Evaluation of coat drying time: Drying is the preliminary step in the formation of edible coating on the product surface and also influences the water activity of the food and it was of importance to dry the coating applied on surface but not of the internal product.

a. Preliminarily, the samples were monitored for **weight loss, water activity and visual quality** (visual and tactile). Two product forms namely, *Fette* (Slices*)* representing crumb and *Mini-pagnotte* (Muffins) representing crust were used. Based on the moisture content and tactile methods, the time of drying for the coating to dry was observed to be 270 minutes for *Fette* (crumb) and 150 minutes for the *mini-pagnotte* (crust). However, the results were not considered substantial due to the discrepancies in the crust thickness.

b. **Evaluation of drying of edible coating on bread using NIR spectroscopy:** Following the significant but not substantial results commercial mini-burger buns (Height- 30 mm, Diameter – 70 mm, Weight – 25.65 ± 0.7g) were chosen for uniform crust thickness. The coating was brushed as a single layer (1L- 2.4± 0.2g) or two layers (2L-3.6± 0.2g) and dried at 25°C (50% R.H) and 60°C (10% RH).

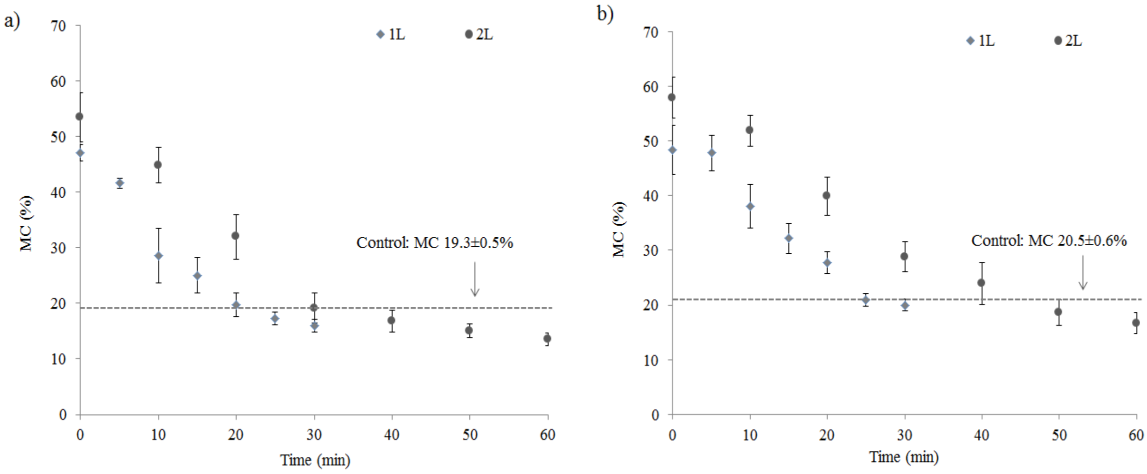

Figure 1. Moisture content over the time for drying temperature of 60 °C; a) top surface, b) bottom surface

The results of the study showed that NIR spectroscopy was a useful tool to monitor the in-line drying behavior of coated breads. At the top surface, the optimal drying time was achieved at about 20 to 30 min, for one and two layers, respectively, while at the bottom, the time was about 25-30 min and 40-50 min, for one and two layers, respectively (*Figure 1*). PLS regression models (*Table 2*) for estimating the optimal drying moment with relation to the evaluated temperatures developed showed a good fit and adequately explains the drying behavior with a R^2 in test set ranging from 0.902 to 0.963.

Table 2: Results of the PLS regressions of the NIR spectra to predict moisture content (%)

Samples		Calibration			Full Cross Validation			Test set		
		PCs	R^2	RMSEC(%)	PCs	R^2	RMSECV (%)	PCs	R^2	RMSET(%)
25°C	Top	1	0.927	2.25	1	0.921	2.45	2	0.918	2.51
	Bottom	8	0.986	1.07	8	0.933	2.28	7	0.922	2.66
60°C1L	Top	5	0.968	1.58	5	0.950	2.04	5	0.932	2.26
	Bottom	2	0.924	2.84	2	0.914	3.08	2	0.902	3.12
60°C2L	Top	1	0.973	2.29	1	0.969	2.49	1	0.963	2.87
	Bottom	2	0.958	2.91	2	0.954	3.08	2	0.937	3.15

A 3.2. Effect of coating on the bread during storage: The weight loss and moisture loss of samples were fitted to non-empirical model proposed by Peleg in Fette and Mini-pagnotte following *A 3.1a* to give two rate constants $1/k_1$ and $1/k_2$ ($R^2 > 0.95$) which defined the initial rate of weight or moisture loss and the equilibrium weight or moisture, respectively. The main conclusions from this study were that effect of coating on bread from dehydration was more evident ($p<0.05$) in *fette* than *mini-pagnotte*, probably due to the uneven crust thickness formed in the baking.

Followed by *A 3.1 b,* the coated commercial bread was stored for 24h and the percentage increase in hardness was observed to be higher in the control samples (C1L: 136.0% and C2L: 271.8%) compared to the samples with the coating (1L: 126.5% and 2L: 231 ,2%). Also, the hardness was negatively correlated with the moisture data (crust), with r = -0.85 and r = -0.94 for samples with one layer and between r = - 0.65 and r = -0.91 for samples with two coating layers.

A 3.3. Application stage and type of coating: In consideration of the significant but not substantial results, it was hypothesized that use of hydrophobic components and application at different stages of baking could have a greater conservative effect on the moisture and structural characteristics of bread during storage. The major stages and results of this phase are:

Phase I: Selection of Hydrophobic component concentration: coatings with different corn oil and butter percentages (0.5, 3.0 and 6.0%) were applied onto commercial bread to choose effective percentage of hydrophobic components. The weight loss of samples stored under controlled conditions were monitored at predetermined times for 30h. The data fitted with Peleg's model resulted in coefficients which were significant ($p<0.001$) with r^2-0.86 to 0.97 indicating a good fit. The lowest initial loss rate ($1/k_1$) was calculated in 6% butter and for oil the loss was similar irrespective of concentration (*table 3)*. For further consideration on textural properties, coating with 6.0% oil and butter were chosen for comparison purposes.

Table 3. Peleg's kinetic constants for weight loss in coated and uncoated commercial bread during storage.

Samples	k_1 (h)*	k_{2*}	Calculated initial loss rate ($1/k_1$) (h^{-1})*	R^2
Uncoated	47.09	3.12	0.021	0.97
Coated	64.27	3.10	0.016	0.97
0.5%Oil	77.79	2.71	0.013	0.94
3.0%Oil	70.00	2.91	0.014	0.94
6.0%Oil	75.38	2.88	0.013	0.87
0.5%Butter	52.87	2.91	0.019	0.97
3.0%Butter	62.41	3.03	0.016	0.97
6.0%Butter	73.95	2.96	0.014	0.86

**All values are significant at $p \leq 0.001$*

Phase II: Application of coating at various stages of baking: In this phase the application of coating was carried out at three baking stages: *Before baking* (BB), *Interrupted baking* (PB) and *After baking* (FB) with a post bake drying step at 60°C for 20min (*from A 3.2*). The overall results showed that the presence of coatings in general reduced the loss of moisture and rate of crumb firming (*table 4*) of the bread during storage when compared to the samples without coating. With regards to the stage of application, FB group had a marked effect followed by PB and BB groups for moisture retention. Whereas, considering the firmness, the PB group had a marked effect, majorly due to the type of baking and a relatively minor effect due to the type of coating. From the results obtained, the optimal stages to apply the coating were found to be before baking (BB) and after complete baking (FB) with post drying step.

Table 4. Crust and crumb firming rates of coated and uncoated baked bread during storage

Firming rate (N/days)		BB	PB	FB
Crust	**Uncoated**	-0.16±0.03b	-0.07±0.03a	-0.16±0.03b
	Coated	-0.10±0.03a	-0.09±0.04a	-0.10±0.03a
	Oil	-0.09±0.03a	-0.09±0.03a	-0.15±0.05b
	Butter	-0.09±0.05a	-0.07±0.02a	-0.16±0.05b
Crumb	**Uncoated**	10.78±1.47 ab	8.6±1.48ab	10.78±1.47b
	Coated	12.69±1.06 b	7.86±1.42ab	6.37±1.13a
	Oil	10.09±0.78 a	7.30±1.05a	11.39±1.29b
	Butter	11.67±1.56 ab	9.77±1.00b	10.45±1.43b

**Means ± SD values columnwise without a common superscript letter differ significantly ($p<0.05$) between treatments.*

5. List of publications produced as part of the doctoral study

Nallan Chakravartula SS, Balestra F, Cevoli C, Fabbri A, Dalla Rosa M (2018) Evaluation of drying of edible coating on bread using NIR spectroscopy (Manuscript-under tutor's review).

Cevoli C, Nallan Chakravartula SS, Dalla Rosa M, Fabbri A (2018) Evaluation of the drying time of coating on sandwich bread: heat and mass transfer finite element model, Bio-sys Eng (paper submitted).

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