2001 MAFMA Final Report

Project Title	**Comparison of Chemical and Physical Properties of Dried Strawberries**
PI	**Keith R. Cadwallader**
Co-PI (s)	**Shelly J. Schmidt and Heo Feng**
Academic Institution	**University of Illinois**
Award Date:	**8/27/02**

The development of a novel film drying method, Refractance Window™ (RW) (MCD Technologies, Inc.) provides a potentially inexpensive alternative to freeze drying (FD) for dehydration of fruit. In our MAFMA project, cosponsored by Kellogg Co. (Battlecreek, MI) with collaboration of MCD Technologies, Inc. (Tacoma, WA), we investigated the potential of RW technology for dehydration of strawberry slices in terms of some important chemical and physical properties as compared the FD counterpart. In particular, we evaluated the retention of flavor, color and ascorbic acid, rehydration capacity, moisture sorption behavior and glass transition temperature.

1. Objective Summary:

To determine potential of Refractance Window™ (RW) drying technology as a lower (energy) cost alternative to freeze-drying (FD) for production of dried strawberry slices. To compare flavor and ascorbic acid retention and physical properties (e.g. color, moisture sorption, glass transition temperature, and rehydration capacity) for RW-dried and freeze-dried product.

2. Objective Accomplishments

All planned objectives were accomplished. Our findings are summarized in the following subsections with a limited explanation of the methodology employed (whenever possible given in footnotes of tables or in captions of graphs).

Preparation of RW and FD strawberry slices. IQF whole frozen strawberries were purchased from Sysco Corp. (Texas). Prior to drying, whole strawberries were thawed and then sliced using an electronic slicer to approximately 1 mm thickness. A visit was made in early December 2002 to MCD Technologies (Tacoma, WA) for preparation of RW dried strawberries using a pilot scale unit. The sliced product was evenly applied to the surface of a conveyor belt (at various speeds so that product residence time on dryer varied: RW-A = 29 min; RW-B = 33 min; RW-C = 37 min; RW-D = 40 min). Water (95°C) was used to transmit heat (indirectly) into the product being dried. Air at 8°C and 46% relative humidity was forced over the bed at an average air velocity of 0.9 m/s to remove the moisture. Dried samples were immediately packed in aluminum-coated polyethylene bags which were flushed with nitrogen, heat sealed and stored at room temperature prior to analysis.

For freeze-drying, strawberry slices prepared as above were immediately (re-)frozen in a forced-air cabinet operating at -24°C for 48 h and then freeze-dried (model J4-34, Vacudyne Inc., Chicago, IL) at 13 in. Hg vacuum for 55h. Product was packaged and stored as above.

Chemical and physical properties. Moisture content, water activity (A_w), glass transition temperature (T_g) and heat of fusion (ΔH) of the RW-dried and FD strawberry slice samples were determined (Table 1). As expected there was a general decline in T_g as a function decreased moisture content and lower A_w, with values being comparable between FD and RW products.

Table 1. Moisture content, water activity and glass transition temperature of refractive window dried and freeze-dried sliced strawberries

Product	Moisture (%)[a]	A_w @ 25ºC[b]	$T_{g,[mid\ point]}$ (ºC)[c]	ΔH (J/g)[c]
FD	1.98	0.16	16.98	0.44
RW-A	5.54	0.24	8.35	0.48
RW-B	4.29	0.22	14.42	0.50
RW-C	3.81	0.21	13.38	0.49
RW-D	2.90	0.20	11.89	0.56

[a]Measured by vacuum oven method at 75ºC. [b]Measured using an Aqualab Series 3 TE water activity meter (Decagon Devices). [c]Measured using a TA Instruments 2920 modulated differential scanning calorimeter (DSC).

Dynamic vapor sorption. Moisture sorption isotherms of strawberry slices were determined at three temperatures (25, 35 and 45°C). Moisture sorption behaviors of both RW and FD product were essentially the same and comparable to literature data for FD strawberries (figure 1). The shape of the sorption curves is common for materials with high sugar content. At low water activities water sorption was negligible, but increased markedly at higher water activity, >A_w = 0.5.

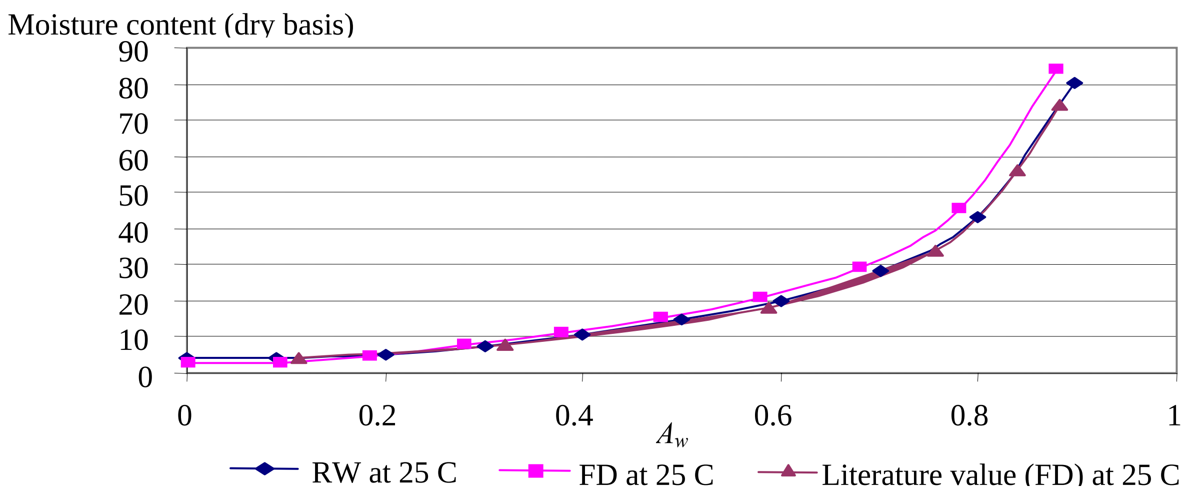

Figure 1. Moisture-sorption isotherm comparison between refractive window dried and freeze-dried sliced strawberries. [Moisture sorption isotherms were determined using a DVS system (series 2000, Surface Measurements Systems, London, UK). Dried strawberry sample (whole slice or powder) was loaded onto a 19 mm quartz sample pan, and placed in the DVS sample chamber. For this study a dm/dt value of 0.001 mg/min for a minimum 10 min was selected as the equilibrium criteria. The sample was allowed to come to pseudoequilibrium (nearly constant weight) and the RH was stepped to one of the specified %RHs at a total flow rate of 500cc, held there for 1000 min (dm/dt window 10 min; minimum stage time 60 min; maximum stage time 1000).]

Rehydration capacity (RC) of freeze-dried strawberry slice samples. The ability of the food material to absorb water has been correlated with its chemical composition and it has been suggested that certain portions of the water insoluble cell wall materials play a significant role in this correlation to rehydration temperature. In the present study, rehydration capacity curves for FD and RW-dried products at 25ºC and 45ºC did not differ [Computations of water loss and solute gain during osmotic dehydration (OD) were based on the assumption that there was no change in the total insoluble solid content of the samples during immersion as suggested by del Valle, J. M., Aranguiz, V., and Leon, H. 1998. Food Res. Intern. 31(8): 557–569. Analysis of data on the rehydrated samples was conducted using the expressions described by Levi, A., Ben-Shalom, N., Plat, D., and Reid, S. D. 1988. Journal of Food Science, 53(4), 1187–1189.].

Flavor and ascorbic acid retention.

Substantial losses were observed for most key aroma components by both drying methods. RW-dried product experienced the greatest loss for most compounds. Especially important was the loss of Furaneol (strawberry ketone), which was mostly retained in the FD product. Some odorants increased during drying, such as (Z)-3-hexenal/hexanal due to lipoxygenase action. Overall, FD product retained more esters and other key aroma components than RW product.

Ascorbic acid (analyzed by HPLC) was also poorly retained in both dried products compared with the original IQF strawberry. The IQF strawberries contained 3.01 mg/g (dry wt) ascorbic acid compared with FD and WD product containing 1.06 and 0.58 mg/g (dry wt), respectively.

Table 2. Concentrations of selected aroma-impact volatile components* of frozen (FZN), freeze-dried (FD) and window-dried (WD) strawberries

	Concentration (ppb, dry wt basis)					
Compound	FZN	FD	WD-A	WD-B	WD-C	WD-D
2,3-butanedione[d]	7780[b]	13200[a]	847[c]	631[c]	579[c]	772[c]
methyl butanoate[d]	5390[a]	2210[b]	341[c]	592[c]	1510[b,c]	1180[b,c]
ethyl 2-methylpropanoate[d]	20.2					
methyl 2-methylbutanoate[d]	87.4[a]	26.1[b]				
(Z)-3-hexenal/hexanal[d]	11100[c]	27700[b,c]	13000[c]	33600[b]	64100[a]	45000[a,b]
ethyl butanoate[d]	7190[a]	1900[b]	510[b]	938[b]	1610[b]	1630[b]
mesifuran[d]	22600[b]	32700[a]	3100c	2300[c]	3020[c]	2300[c]
ethyl 2-methylbutanoate[d]	293					
ethyl 3-methylbutanoate[d]	36.6					
Furaneol[d]	131000[a]	116000[b]	39900[c]	49300[c]	43500[c]	44800[c]

*Representative compounds selected based on Schieberle, P. and Hoffman, T. 1997. J. Agric. Food Chem. 45: 227-232. [a-c]Values in rows having different superscripts differ ($p<0.05$). [d]Analysis by SPME-GC-MS according to Zhou, et al. (2002) with modifications. [e]Analysis by HPLC according to Sans, C., Pérez, A.G., and Richardson, D.G. 1994. J. Food Sci. 59: 139-141.

Color. Results of color measurements for the three strawberry products are given in Table 3. The total color change, ΔE, and darkness factor (*b*/a**), can be used to characterize the overall color quality of the strawberry products. The RW dried strawberries had the more pronounced color degradation (ΔE), i.e. more noticeable browning, than the freeze-dried product

Table 1. Results of color measurement ($L^*a^*b^*$), darkness factor (b^*/a^*), and total color difference, ΔE, for IQF, freeze-dried, and Refractance Window™ dried sliced strawberries

Treatment	***L****	***a****	***b****	***b*/a****	**ΔE**	***H****
IQF strawberry slices	44.8±0.6	33.3±0.1	17.5±0.3	0.52	0	27.47
Freeze dried slices	39.3±0.1	38.1±0.3	21.4±0.1	0.56	8.31	29.25
RW-B2	33.3±0.5	24.4±0.1	18.1±0.4	0.74	14.55	36.50
RW-D2	37.4±0.3	26.6±0.4	20.2±0.3	0.76	10.35	37.23
Freeze dried powder	48.9±0.5	38.5±0.2	19.7±0.1	0.51	6.93	27.02
RW dried powder	38.4±0.3	38.4±0.5	23.4±0.1	0.60	10.10	30.96

Color of IQF, freeze-dried (FD) and Refractance Window™ (RW)-dried strawberries were compared using a Hunter Lab colorimeter (LABSCAN II: SN-13889, Hunter Associates Lab., Inc.).

3. Unexpected findings, if any. The extent of product quality deterioration in refractive window (RW) dried product was much higher than expected. The very close similarity in moisture-sorption behavior between RW and freeze-dried product also was unexpected.

4. Practical impacts of research efforts.

a. Short Term Impacts. Moisture-sorption isotherms and other physical data (e.g. glass transition and rehydration capacity data) indicated that Refractive Window™ (RW) drying can produce a dehydrated sliced strawberry product having nearly the same moisture sorption behavior as its freeze-dried (FD) counterpart. However, RW product showed greater quality deterioration in terms of flavor and ascorbic acid losses as well as color degradation (browning). These losses mostly can be attributed to the prolonged period needed to dehydrate the sliced product by RW as compared to a slurry (usual method of application) which takes much less time to dehydrated (factor of about 10X). In the near term it is recommended that RW not be considered in its present form as a viable alternative to freeze-drying for production of dehydrated sliced strawberries.

b. Long Term Impacts. Comparable moisture-sorption behavior between RW and FD product is a favorable outcome and indicates that with greater R&D efforts the RW technology might be able to produce a high quality dehydrated sliced strawberries with comparable moisture-sorption behavior. Shorter residence time during the RW process should lead to better retention of flavor and ascorbic acid, and less browning of product. Future efforts should be directed toward optimizing of the engineering parameters, focusing mostly on quality retention and less so on moisture sorption studies.

5. If you are also making reports to other funding agencies in the course of this research work, please include a copy of that report. N/A

6. If any publications resulted from the research, please include a copy if possible and references None to date.