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Influence of Surface-Active Agents on the Rehydration of Dried Chard Leaf Tissue

Wayne J. McIlrath and Elias D. Dekazos
Department of Botany, University of Chicago, Chicago, Illinois
and
Karl R. Johnson
Quartermaster Food and Container Institute, Chicago, Illinois

SUMMARY

Vacuum-oven-dried Swiss chard leaf tissues were dehydrated in aqueous preparations of fourteen surface-active agents. In general the nonionic surfactants accelerated the rate of water absorption without appreciably influencing the final degree of rehydration. Anionic agents, on the other hand, accelerated rehydration slightly, and at 0.5% concentration gave a highly significant increase in the total water absorbed. Some of the anionic detergents induced a binding of water that withstood a force of 1000 × G.

INTRODUCTION

The inability to attain adequate rehydration of certain dried plant material has been a serious handicap in obtaining an acceptable product with certain fruits and vegetables. The reasons for this lack of rehydration remain relatively obscure. The use of surface-active agents to increase wetting has long been a practice in agriculture, with some limited applications in the food industry (Schwartz and Perry, 1949). To the authors' knowledge, however, there are no published data on the use of such agents in rehydrating dried foods.

The present work was therefore undertaken to determine the effects of a number of such agents on the rate and degree of rehydration of dried Swiss chard leaf material. This plant material was utilized as a model system in that a supply of uniform material could be obtained at all times.

EXPERIMENTAL METHODS

The Swiss chard plants used were grown in sand culture in a controlled-environment room under conditions previously described (Vergara and McIlrath, 1960). A complete nutrient solution (Hoagland and Arnon, 1950) was applied to these cultures three times per week, and distilled water on the remaining days.

Leaves of uniform age were harvested, 20 mm disks were rapidly punched from them with a cork borer, and the disks were placed in a vacuum oven for drying. In punching the disks, care was taken to avoid major veins. Disks were dried 24 hr at 40°C with a vacuum of 29 Hg. The dried leaf tissue was stored in a desiccator over $CaCl_2$ until used.

The leaf disks were dehydrated by submerging them in the rehydrating liquid maintained at 21°C in Petri dishes. For weighing, the rehydrated disks were removed from the solution, quickly blotted dry of external moisture with filter paper, and weighed rapidly on a Roller Smith balance. Ten disks were normally included in each treatment. Rehydration ratios were calculated by dividing rehydrated weights by dry weights of the disks (von Loesecke, 1955).

The leaf disks used in the centrifugation experiments were rehydrated and weighed as indicated above and then placed on moist filter paper in the bottom of stainless-steel boxes. These boxes, which had screen bottoms and sheet-metal lids, had curved bottoms designed to fit closely against the circumference of a special centrifuge drum head. The disks were subjected to centrifugation of 1000 × G for 30 min, and then weighed again. Disks cut from fresh tissue, and such disks cut and soaked in water prior to centrifugation, were included to check on evaporative drying during centrifugation. In no case was it observed that the fresh tissues lost moisture during centrifugation.

The surface-active agents studied were those recommended by several manufacturers (Table 1). It was indicated to these firms that only those agents were to be considered that were known or would prove to be non-toxic to animals if consumed in moderate quantities. In most cases, no toxicological information was supplied by the manufacturer, so it is uncertain how carefully they applied this criterion in their selection. The concen-

Table 1. Surface-active agents used in rehydration experiments.

Name	Nature	Manufacturer
Nonionic		
Dispersant NI-W	Alkylphenyl polyethoxyethanol	Oronite Chemical Co.
Nonic 218	Polyethylene glycol tertdodecylthioether	Pennsalt Chemicals Corp.
Pluronic F68	Polyol	Wyandotte Chemical Corp.
Span 60	Sorbitan monostearate	Atlas Powder Co.
Sterox AJ	Aliphatic polyoxyethylene ether	Monsanto Chemical Co.
Sterox CD	Polyoxyethylene ester of tall oil	Monsanto Chemical Co.
Surfonic N-95	Adduct of nonylphenol alcohol and ethylene oxide	Jefferson Chemical Co.
Surfonic TD-90	Adduct of tridecyl alcohol and ethylene oxide	Jefferson Chemical Co.
Tween 60	Polyoxyethylene sorbitan monostearate	Atlas Powder Co.
Tween 80	Polyoxyethylene sorbitan monooleate	Atlas Powder Co.
Anionic		
Aerosol OT	Dioctyl ester of sodium sulfosuccinic acid	American Cyanamid Co.
Duponol C	Sodium lauryl sulfate	E. I. du Pont de Nemours
Oronite D40	Sodium alkyl aryl sulfonate	Oronite Chemical Co.
Santomerse 85	Alkyl aryl sulfonate	Monsanto Chemical Co.

Table 2. Influence of various surface-active agents on the rehydration ratio of vacuum oven-dried Swiss chard leaf disks; rehydrated for 40 min.

	Rehydration ratios at concentrations (%):					
Surface-active agent	0.00	0.001	0.01	0.1	0.25	0.5
Nonionic						
Dispersant NI-W	2.32	3.31	2.54	2.90	2.31	2.56
Nonic 218	2.49	2.14	2.65	3.29	3.69	3.88
Pluronic F68	2.21	2.11	2.41	2.40	2.66	2.32
Span 60	2.34	2.63	2.46	2.34	2.45	2.46
Sterox AJ	2.40	2.40	3.17	3.94	2.91	3.17
Sterox CD	2.34	2.62	2.93	2.77	2.45	2.45
Surfonic N-95	2.12	2.30	2.92	3.12	2.86	2.98
Surfonic TD-90	2.07	2.27	2.47	2.47	2.62	2.97
Tween 60	2.34	2.36	2.45	2.55	2.42	2.42
Tween 80	2.43	2.54	2.78	2.72	2.38	2.75
Anionic						
Aerosol OT	2.37	2.23	2.73	2.75	2.72	2.73
Duponol C	2.32	2.34	2.65	3.09	3.18	3.17
Oronite D40	2.38	2.33	2.53	2.86	3.00	3.04
Santomerse 85	2.77	2.72	2.81	3.67	3.57	3.05

trations used were prepared on a weight basis of the material as supplied, without reference to the percentage of active agent in the material. Since most of the products contained high levels of active agent, only small differences existed among the various agents at a given concentration. The only one widely variant from the rest was Oronite D40, reported to contain only 40% active material. Aqueous solutions or emulsions, depending on the solubility of the agent, were used throughout.

RESULTS AND DISCUSSION

As expected, the higher concentrations of surface-active agents used in this study accelerated absorption of water by the dried tissue. Somewhat unexpected, however, was that the 0.001% level of five of the materials (Nonic, Pluronic, Aerosol, Oronite, and Santomerse) appeared to slow tissue rehydration (Tables 2, 4). Three of the agents at this concentration also lowered the final degree of rehydration. It is obscure why this low level inhibited water absorption whereas higher concentration accelerated it. It is not known whether these responses can be correlated with the ion or micellar structure of the surface-active agent; the structure is presumably determined by concentration of the agent (Putnam, 1948).

Although the rehydration ratios of disks in nonionic agents were higher at 24 hr than at 40 min, the large differences in ratios between disks rehydrated in distilled water and those in the surface-active materials at 40 min were greatly reduced at 24 hr (Tables 3–5). Thus it would appear that, except for the Tweens and Span, these agents greatly increased the rate of absorption, but did not result in a highly significant increase in total hydration at equilibrium. Although the anionic agents did not in all cases accelerate absorption, their presence at high concentrations resulted in a significantly greater water content after 24 hr (Tables 3–5). Sarvacos and Charm (1962) found no such effect on rehydration ratios when surface-active agents were applied to tissues prior to drying.

Because of the apparent capacity of the anionic agents to induce a greater total water uptake, the status of this water was of interest. To determine the degree to which this water was bound, tissues rehydrated in a 0.5% concentration of the anionic surfactants were subjected to centrifugation. As previously noted, rehydration ratios were significantly higher in these tissues than in tissues rehydrated in distilled water (Table 5). After centrifugation, tissues rehydrated in Aerosol and Duponol still had significantly higher ratios. The ratios of tissues in Oronite and Santomerse, however, were not significantly different from that for tissue in distilled water.

It is unknown why anionic agents produced a significantly greater degree of hydration while the nonionic ones did not. One is tempted, however, to point to the presence of the reactive ionic groups of the anionic agents and their lack in the nonionic materials. Whether the difference among the anionic surfactants is related to the

Table 3. Influence of various surface-active agents on the rehydration ratio of vacuum oven-dried Swiss chard leaf disks; rehydrated for 24 hr.

Surface-active agent	Rehydration ratios at concentrations (%): 0.00	0.001	0.01	0.1	0.25	0.5
Nonionic						
Dispersant NI-W	4.03	4.58	4.20	4.35	3.85	4.29
Nonic 218	4.29	4.23	4.17	4.67	4.69	4.87
Pluronic F68	4.04	4.01	4.15	4.27	4.13	3.88
Span 60	4.41	4.84	4.77	4.39	4.71	4.87
Sterox AJ	3.87	3.92	4.89	4.12	4.25	3.95
Sterox CD	4.12	3.85	4.44	4.34	4.07	4.37
Surfonic N-95	3.81	3.77	4.28	4.30	4.24	4.40
Surfonic TD-90	3.75	3.78	3.97	4.00	4.14	4.25
Tween 60	4.30	4.76	4.66	4.78	4.54	4.53
Tween 80	4.23	4.65	4.57	4.77	4.40	4.35
Anionic						
Aerosol OT	4.58	4.27	4.59	5.08	5.09	5.80
Duponol C	3.95	4.12	4.27	4.69	5.50	5.93
Oronite D40	3.97	4.18	4.23	4.56	5.05	5.32
Santomerse 85	4.11	4.18	4.27	5.03	5.06	5.02

Table 4. Change in degree of hydration as a result of various concentrations of surface-active agents expressed as the percentage difference from rehydration in distilled water.

Surface-active agent	Rehydration time	% change at concentrations (%): 0.001	0.01	0.1	0.25	0.5
Nonionic						
Dispersant NI-W	40 min	42.7	9.5	25.0	−0.4	10.3
	24 hr	13.6	4.2	7.9	−4.5	6.5
Nonic 218	40 min	−14.1	6.4	32.1	48.2	55.8
	24 hr	−1.4	−2.8	8.9	9.3	13.5
Pluronic F68	40 min	−4.5	9.0	8.6	20.4	5.0
	24 hr	−0.7	2.7	5.7	2.2	−4.0
Span 60	40 min	12.4	5.1	0.0	4.7	5.1
	24 hr	9.8	8.2	−0.5	6.8	10.4
Sterox AJ	40 min	0.0	32.1	64.2	21.3	32.1
	24 hr	1.3	26.4	6.5	9.8	2.1
Sterox CD	40 min	12.0	25.2	18.4	4.7	4.7
	24 hr	−6.6	7.8	5.3	−1.2	6.1
Surfonic N-95	40 min	8.5	37.7	47.2	34.9	40.6
	24 hr	−1.0	12.3	12.9	11.3	15.5
Surfonic TD-90	40 min	9.7	19.3	19.3	26.6	43.5
	24 hr	0.8	5.9	6.7	10.4	13.3
Tween 60	40 min	0.9	4.7	9.0	3.4	3.4
	24 hr	10.7	8.4	11.1	5.6	5.3
Tween 80	40 min	4.5	14.4	11.9	−2.0	13.2
	24 hr	9.9	8.0	12.8	4.0	2.8
Anionic						
Aerosol OT	40 min	−5.9	15.2	16.0	14.8	15.2
	24 hr	−6.8	0.2	10.9	11.1	26.6
Duponol C	40 min	0.9	14.2	33.2	37.1	36.6
	24 hr	4.3	8.1	18.7	39.2	50.1
Oronite D40	40 min	−2.1	6.3	20.2	26.1	27.7
	24 hr	5.3	6.5	14.9	27.2	34.0
Santomerse	40 min	−1.8	1.4	32.5	28.9	10.1
	24 hr	1.7	3.9	22.4	23.1	22.1

Table 5. Moisture lost by rehydrated vacuum oven-dried Swiss chard leaf disks subjected to centrifugation for 30 min at 1000 × G. Tissues rehydrated in 0.5% concentration of surface-active agents for 24 hr.

Surface-active agent	Rehydration ratio	Water lost on centrifugation (%)	Rehydration ratio after centrifugation
None (distilled watr)	4.1	25.3	3.4
Aerosol OT	4.7[a]	20.7	4.1[a]
Duponol C	5.5[a]	26.5	4.3[a]
Oronite D40	5.0[a]	32.3	3.7
Santomerse 85	5.2[a]	36.0	4.1

[a] Statistically different from distilled water at 1% level.

size and structure of their hydrocarbon portions is not known.

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