SOME PROPERTIES OF FOAM SPRAY DRIED WHOLE EGGS

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ABSTRACT

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by John G. Reagan

Frozen liquid whole eggs were thawed and spray dried using two different nozzle sizes and two different levels of injected nitrogen in addition to a non-nitrogen injected treatment. Some of the whole egg powder was put through instantizing equipment. Total solids, solubility index, pH, dispersibility, bulk density, filtration rate and particle size distribution were determined on the egg powder from each drying method and instantizing procedure. The particle size distribution was determined through the use of the Coulter Counter, model B.

"Flowability" was not measurably improved by foam spray drying or by instantizing. The instantizing procedure following spray drying did not appear to be effective in this study since both solubility and dispersibility decreased. Instantizing the whole egg powder had little effect on the particle size distribution and bulk density. It appeared instantization did not occur.

Foam spray dried whole egg powder has increased solubility, larger particles, decreased bulk density and is slightly more dispersible than the conventional (non-nitrogen injected) spray dried whole egg powder.

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INTRODUCTION

Eggs and egg products are very perishable unless frozen, dried or refrigerated (shell eggs) until utilized. Dehydration not only offers a means of preserving quality, but also reduces the packaging, handling, storing and transportation costs.

Koudele and Heinshon (1960) reviewed the history of the egg drying industry. They reported that in the United States, the idea of drying eggs was conceived in the late 1800's. However, the first successful commercial egg drying operation apparently took place in China, where German engineers introduced dried eggs in the early 1900's. Stauf was credited with the invention of the spray dryer in 1901. The belt type dryer for "flake" whole egg and yolk was introduced by Keith and Hussey in 1907, and in 1913 Gray and Jensen produced a cyclonic type spray dryer (Berquist 1964).

During the early 1930's the drying industry for albumen and yolk was re-established in the United States. However, with the outbreak of World War II, the production of dried whole eggs dwarfed that of albumen and yolk. Drying of whole eggs reached a peak in the United States during 1944 when over 300 million pounds of dried whole egg were produced.

The introduction of gas into the liquid feed line is not a new idea as it was done in 1922 by Heath and Washburn when they introduced a somewhat soluble inert gas such as carbon dioxide or nitrogen under pressure during the spray drying of milk. The most successful modification of this method was introduced by Hanrahan and Webb (1961). This method of gas injection under pressure into the liquid feed line is currently known as foam spray drying.

Physical, chemical and functional properties of eggs may be altered during a drying process. Thus advances in drying techniques are sought to produce products which will perform as well or better than the fresh egg. Foam spray drying was introduced by Heath and Washburn (1922) in an attempt to improve some of the physical properties of the dried product. Normal spray dried eggs lack "flowability" and "instantizing" characteristics desired in the product.

This research was conducted to evaluate some of the physical and chemical properties of foam spray dried whole eggs, and to relate these properties to possible improvements in functional characteristics of the resulting products. At the present time there is a general lack of information in the literature concerning the properties of foam spray dried eggs in comparison with conventional spray dried products.

LITERATURE REVIEW

Particle Size

Pearce et al. (1946) reported using a "RoTap Shaker" with an assortment of sieves to separate dried whole egg powder into portions according to particle sizes. This machine shakes the dried food continuously and taps the top cover of the sieves frequently during the operation. In this study, powder of particle size small enough to pass through an 80 mesh (U.S.) screen or sieve appeared to have better baking properties than coarser material. Mori (1964) used the RoTap Shaker and the Coulter Counter to determine the particle size analysis of dried milk. Particles which passed through a #60 sieve (U.S.) (screen) were subjected to the Coulter Counter analysis. The Coulter Counter counts particles electronically. Particles are suspended in a solution through which an electrical current can pass. As the particles pass through an opening in a tube the electrical current is disrupted and the impulse is registered and counted automatically when the particle size exceeds the limits as set on the machine. Mori found he needed both the shaker and Coulter Counter for optimum analysis of instantized milk powders because of the wide range in particle size.

Lightbody and Fevold (1948) reported that spray dried egg particles were hollow spheres from 7 to 120 microns in diameter. The atomization conditions, nozzle orifice size, liquid line pressure, liquid viscosity and solids content are among factors known to affect particle size.

The Coulter Counter (Anon 1965a) reportedly can be used for determining numbers of particles as well as a particle size distribution for materials which can be suspended in a solution condusive to the passage of an electrical current. Several other workers have reported other means of determining particle size or surface areas in milk powders, Fox et al. (1963), Janzen et al. (1953), Berlin et al. (1964) and Shaw et al. (1946).

Solubility

The Institute of American Poultry Industries (1962) recommended Stuart's Solubility Index for evaluating dried egg solids and for a possible purchase specification. The amount of protein precipitate is measured from a 1.5 gram sample of egg powder and 5 ml of the subsequent filtrate. Bishov and Mitchell (1964) described their method for a similar solubility study.

Dispersibility

Sugihara et al. (1962) reported that fluff drying, agglomeration or gas impregnation prior to spray drying of liquid whole egg, to which corn syrup solids had been added, improved the dispersibility strikingly over conventional spray dried whole egg powder. Two methods for determining dispersibility of whole egg powder were found (Downs 1966 and Miller et al. 1959). In Down's method the egg powder is reconstituted to a known total solids content. After mixing, a 5 gram sample of the reconstituted egg is dried and the resulting total solids content compared with the known total solids content.

Flowability

Several methods for improving the flowability of dried egg and yolk powders have been attempted. The usual reason given for the clumping, sticking or clinging together of whole egg and yolk powder is the relative high fat content. Whole egg powder is usually 40+ per cent lipid material and yolk powder is around 65 per cent lipid material. Among the methods tried to improve flowability of egg powders have been 1) coating the egg particle, 2) agglomeration or instantizing and 3) foam drying.

Forsythe et al. (1964) reported the use of a colloidal silica gel preparation in dried egg yolk powders. The colloidal silica gel was used to coat the individual yolk particles or clusters of yolk particles so the fat does not come in contact between the yolk particles or clusters. This method was found to be effective as measured by a standard screen test.

Agglomeration or instantizing has been used primarily for dried milk prepared for home use in the past several years. These processes can include agglomeration by wetting and then redrying or by coating, Mori (1964).

Foam Drying

Foam drying can be divided into two principal methods: 1) foam mat drying and 2) foam spray drying. The foam mat drying is also called film drying or "puff" drying. The principle is drying under high vacuum at low temperature with the incorporation of nitrogen before the concentrate goes through the final homogenizer. Dried milk, tomato juice, egg albumin and other liquids and purees have been produced in this manner, Mori (1964), Ginnette et al. (1963) and Copley and VanArsdel (1964).

Foam spray drying involves injection of a gas such as nitrogen or air under pressure into the liquid feed line between the pressure pump and the spray nozzle by means of a mixing chamber in the liquid feed line. Heath and Washburn (1922) first reported this method and the modifications by Hanrahan and Webb (1961) have been the most successful when used for drying high acidity whey. The process has also been tried with cheese (Finch 1966) and milk (Hanrahan et al. 1962 and Bell et al. 1963).

Total Solids

Low moisture levels in dried egg products are essential for optimum quality stability. The military specifications for dried whole egg (Anon 1965c) establishes a minimum of 97.5 per cent total solids and the military specifications for a dehydrated egg mix (Anon 1965b) sets a minimum of 98 per cent total solids content. The minimum total solids recommended for commercial purposes is 95 per cent, Forsythe and Miyahara (1959), Miyahara and Berquist (1961) and Forsythe (1964).

Functional Properties

Wolfe (1967) obtained representative samples of the same whole egg powders as used by this author. She reported no differences in functional properties of the whole egg powders when used in custards.

EXPERIMENTAL PROCEDURE

Frozen whole eggs, adjusted to 26 per cent total solids, were obtained from a commercial source. Sixty pounds of liquid whole eggs were spray dried for each treatment.

Spray Drying

The frozen whole eggs in 30 pound tin containers were thawed under cold running tap water for approximately 16 hours and then placed in 10 gallon stainless steel milk cans. The milk cans were placed in a water bath at 60°C and the liquid egg temperature brought up to 57°C prior to the drying process. All liquid eggs to be foam spray dried required nitrogen injection at a constant rate into the liquid egg immediately after passing through the homogenizer and prior to spraying.

The spray dryer and supporting equipment consisted of the following:

1. Waukesha positive pump - fed liquid whole egg into the high pressure pump (homogenizer).

2. Cherry Burrell high pressure pump variable speed drive (homogenizer).

3. Nitrogen injection chamber with source of nitrogen under pressure.

4. C. E. Roger horizontal spray dryer. Capacity of 250 pounds N.F.D.M. per hour, three nozzles, gas fired and cyclone separator.

5. Taylor instrumentation panel to record inlet and outlet air temperature.

6. Nozzles. The SX 69 and SX 64 with number 17 core from the Spraying Systems Company were used.

The samples of eggs were spray dried as shown in Table 1. The foam spray treatments were a modification of the method suggested by Hanrahan and Webb (1961). The nitrogen pressure exceeded the homogenization pressure by approximately 100 psi. A Brooks Rotameter metered the nitrogen into the stream of liquid whole egg as the egg passed through the injection chamber.

The egg powder was then collected from the dryer and placed in Cryovac bags which were evacuated, sealed, and stored at 3°C for further testing.

Approximately one-half of the dried egg powder from each treatment was instantized using a Blaw-Knox Instantizer, Series A-20 at 6-7 psi steam. Intake temperature was 143°C and the exhaust temperature was 82°C. After instantizing once, half of the instantized product was instantized a second time under the same conditions.

TABLE 1. Conditions of spray drying

Spray drying method	Nozzle/ core	Nozzle diameter	Homogenization pressure	Nitrogen per gal.	Inlet temp.	Outlet temp.
	No.	Inches	PSI	Cu. ft.	°C	°C
Conventional	64-17	.036	2500[1]	none	140	93
I	64-17	.036	1050	0.3	117	81
II	64-17	.036	1050	2.0	117	80
III	69-17	.0292	900	0.3	116	80
IV	69-17	.0292	900	2.0	118	80

[1]An homogenization pressure of 2500 psi is recommended for this machine. However, the nitrogen available only had 1000-1150 psi, the nitrogen injected spray drying methods had homogenization pressures approximately 100 psi less than the available nitrogen supply.

Total Solids

The total solids content of the dried egg products was determined by the method proposed by the Institute of American Poultry Industries (1962). Two grams of a well mixed sample were placed in a previously dried and tared aluminum moisture dish with cover. The cover was loosened and placed in a vacuum oven at 100°C for 5 hours. The sample was removed from the oven, placed in a desiccator to cool to room temperature and then weighed. The results were reported as per cent total solids.

Solubility

Stuart's Solubility Method was used as outlined by the Institute of American Poultry Industries (1962).

One and one-half grams of dried whole egg powder were added to 50 ml of distilled water in a 250 ml Erlenmeyer flask with a screw cap top. The temperature of the water was 21-24°C. The contents of the flask were thoroughly agitated to obtain a uniform dispersion. The flask and contents were allowed to stand for 30 minutes at room temperature. The contents of the flask were agitated vigorously and filtered through a Whatman #12 fluted filter paper. The first 10 ml of filtrate were collected in a 10 ml volumetric flask. Five ml of the 10 ml filtrate were transferred, using a volumetric pipette, to a 15 ml tapered centrifuge tube which was graduated in 0.1 ml subdivisions. Five ml of 0.1M sodium acetate buffer (pH 4.6) were added to the centrifuge tube. The sodium acetate buffer was made with 102 ml of 0.1N acetic acid and 98 ml of 0.1 N sodium acetate. The pH was adjusted to 4.6. After the buffer was added, sufficient water was added to bring the contents to a final volume of 15 ml. The centrifuge tube was transferred to a water bath at 100°C for two minutes, cooled to approximately room temperature in a second water bath and then centrifuged at 2,000 rpm for 6 minutes. The volume of centrifuged precipitate was read to the nearest 0.1 ml graduation. The number obtained was recorded as Stuart's Solubility Index.

Time of Filtration

An estimate of filtration rate was determined as the total time elapsed between the addition of the egg suspension to the filter paper and the collection of the first 10 ml of the filtrate in the volumetric flask.

pH

Five grams of dried egg powder from each treatment were mixed with 30 ml of deionized water in a beaker. The pH of the egg suspension was determined by placing the electrodes in the beaker containing the egg sample. A Beckman Zeromatic pH meter was used, and all pH measurements recorded to the nearest 0.1 of a unit.

Dispersibility

A modification of the method suggested by Downs (1966) was used. The following is used to determine how much water is needed for reconstitution of a 60 gram sample of dried egg powder to a desired total solids content of 30.6 per cent:

1. Determine the total solids content of the whole egg powder as outlined previously.

2. Multiply 60 grams by total solids (1) to determine total solids content of the 60 gram sample.

3. Multiply (2) by 100 and divide by 30.6 (the desired per cent total solids when reconstituted) to determine the total amount of reconstituted egg desired (grams).

4. From (3) subtract the weight of the sample of whole egg powder (60 grams) to determine the grams of water which must be added to have a total solids content of 30.6 per cent.

Before mixing the egg samples, the vacuum oven and forced air drying oven (to be used later) were preheated to 100°C. A Kitchen Aid model K5-A mixer with paddle was allowed to warm up for 10 minutes and the speed of the paddle was adjusted to 130 planetary rpm. Water was divided equally between two beakers after the pH was adjusted to 7.0. The egg powder was weighed into the mixing bowl and the bowl placed on the mixer. One-half of the water was added to the mixing bowl and the paddle attached to the mixer. The egg and water were mixed for 30 seconds. The sides of the bowl and paddle were scraped and the slurry was mixed an additional 30 seconds. The bowl and paddle were scraped a second time. The remaining water was added and the slurry mixed for an additional 30 seconds. The paddle was scraped and the bowl was removed from the mixer. The slurry was strained immediately through an 8 inch number 20 sieve into an 8 inch collection pan. The slurry was allowed to drain 5 minutes and the contents of the collecting pan were transferred to a 500 ml beaker. Five gram portions of the strained slurry were weighed into dry and previously tared aluminum moisture dishes with covers. The slurry was mixed before the weighing process to obtain a uniform sample. The samples were placed in the forced air oven at 100°C to evaporate the excess moisture until the slurry thickened. The samples were then transferred to the vacuum oven and dried at 98-100°C under 30 inches of vacuum for 5 hours or until a constant weight was obtained. Dry air was released into the vacuum oven, the samples removed and placed in a desiccator, cooled to room temperature and then weighed. The weight of the residue divided by the weight of the liquid sample determined total solids content of the sample. The total solids content of the reconstituted sample divided by the total solids content representing complete dispersion (.306) multiplied by 100 determined per cent dispersibility.

Particle Size Analysis

Several attempts were made to separate the dried whole egg powder according to size by use of a RoTap shaker.

Placing the egg powder on the top sieve and then shaking resulted in the egg powder forming little balls about the size of peas on the top two sieves. Very little powder went past the second sieve (number 20). To eliminate the effect of moisture the sieves (a total of six), the bottom collection pan and the top lid were dried in an oven, removed after drying and the sieves taped together with 2 inch masking tape, the egg sample added, the lid placed on the top sieve and sealed with the masking tape. The result was a closed system so air could not get in, however the separation did not improve. Next the whole egg powder was dried in an oven before shaking in the closed system but again there was no improvement in separation. Dried rice was added to the top of each sieve and the sieves taped. This increased separation somewhat but was not entirely satisfactory. The shaking time was varied but increased separation did not take place after 2 hours when compared with 15 minutes.

Since the particles tended to cling together and would not pass through the sieves without the use of an external force, the Coulter Counter (Anon 1965a) Model B was used to evaluate the particle size distribution. The Coulter Counter consisted of a sample stand, an amplifying unit and a small vacuum pump. A beaker containing the sample suspended in a solution containing 10 grams ammonium thiocyanate per liter of isopropyl alcohol (vehicle) was placed on the sample stand in such a manner that a tube with a 400 micron diameter opening was immersed in it. Previously the ammonium thiocyanate-isopropyl alcohol solution was filtered through a Millipore filter with a 0.45 micron pore size disc. A 4 per cent ammonium thiocyanate-isopropyl alcohol solution is recommended by the manufacturer but no difference could be found using 10, 20, 30 or 40 grams ammonium thiocyanate per liter isopropyl alcohol, thus the lowest concentration of ammonium thiocyanate was used.

The aperture filled with the vehicle was connected to a vacuum system which provided a flow of a measured volume of vehicle, 2,000 microliters for the 400 micron diameter aperture tube, through the aperture in the tube. Platinum electrodes were located within and without the aperture tube and a constant voltage was maintained between them.

The vehicle flowing through the aperture exhibited a resistance which was changed when a particle passed through the sensing zone. This change in resistance was amplified and counted. The size of particles was reflected by the magnitude of change in resistance which was manifested as pulse height on an oscilloscope. The number of particles passing through the aperture tube opening was counted electronically. An adjustable threshold setting permitted the counting of only those pulses which exceeded a given height on the oscilloscope. In this manner the minimum size of the particles was regulated. To increase the range of pulse height, and thus the range of particle size measured, it was possible to decrease the resistance across the electrodes and to increase the amplification gain. The volume of vehicle passing through the counting aperture was regulated by the vacuum system provided with a traveling mercury column which activated starting and stopping probes preset for known volume displacements.

The apparatus was standardized by determining the half count of a sample of uniform size particles with known diameter in microns (ragweed pollen). The settings of amplification gain, threshold and resistance across the platinum electrodes were adjusted in order to calculate a calibration factor (k) for each aperture tube. This factor, which corresponded to the known diameter of the standard, was in turn used to calculate settings to give other particle diameters.

Counting of particles was then made on an unknown sample at pre-determined settings, starting with the largest particles. Counts were taken at 10 micron intervals down to the 10 micron level which was the lowest useable reading using the 400 micron diameter aperture tube. Smaller diameter aperture tubes were tried but became clogged by the larger egg particles. No method was found which would separate the larger particles from the smaller particles. Coincidence of particles passing through the aperture at high counts was compensated for by using a coincidence factor which was a function of the number of particles actually counted, size of the aperture diameter opening and volume of vehicle passing through the aperture opening. The adjusted counts were corrected for each interval in diameter. The summation of these factors comprised the total volume of particles in a given volume of vehicle. From these data, the percentage weight distribution was calculated, assuming a uniform density for all particles and a spherical shape.

A stirrer located on the sample stand kept the particles in a uniform suspension during counting. Counts did not change for the same settings during the counting period. Therefore, it was assumed the particle size did not change nor were the particles dissolved in the vehicle medium.

Bulk Density

A modification of the bulk density method reported by Mori (1964) for milk powder was used to evaluate dried whole egg powders. Sufficient egg powder was sifted through a #10 sieve to loosely fill a previously weighed 100 ml graduated cylinder. A loose pack bulk density was not determined since the whole egg powder was not free flowing enough to eliminate large air pockets when placed in the cylinder without tapping the cylinder. The cylinder was tapped gently for approximately 3 minutes using a ball point pen which had been inserted inside a 1/4 inch diameter rubber tubing 4 inches long. A 3 minute tapping period was sufficient to give a constant volume reading. The volume of packed whole egg powder was read to the nearest ml and the cylinder and egg powder were weighed. The results were reported as grams/ml.

Visual Observations of Dispersibility

To estimate, by visual means, the relative dispersibility of whole egg powders, a series of observation tests were carried out on the egg powder from each treatment. A 250 ml volume of distilled water was placed in each of several 400 ml beakers. A 0.25 and a 0.50 gram sample of egg powder from each treatment were separately sieved through a 4 inch #10 sieve into separate beakers. The 0.25 gram sample was allowed to sit quiescently to see how rapidly the particles would sink without any mixing. The final observation was made after the solution stood for 4 hours. The second sample (0.50 gram) was sieved in similar manner then stirred for approximately 30 seconds and observed for clusters of particles which did not disperse but remained floating.

RESULTS

Total Solids

All of the dried egg products in this study had total solids exceeding 95 per cent (Table 2). No apparent differences in total solids content were noted between control samples and those foam spray dried.

In these dried egg products, the samples instantized once contained an average of only .29 per cent less total solids than the controls and those instantized twice which contained .60 per cent less total solids. These minor differences in total solids content would probably not affect the other factors evaluated. Mori and Hedrick (1965) reported moisture increases of 1.16 to 1.72 per cent for dry non-fat milk powders passing once through the same type of instantizer used in this study. They also reported that higher inlet temperatures of the instantizer resulted in lower increases in moisture uptake.

Solubility

The foam spray dried egg powder appeared to be more soluble than the conventional spray dried egg product (Table 3). A slight decrease in solubility was noted when the egg

TABLE 2. Total solids of egg samples spray dried and treated by different procedures

Spray drying method	Number of times instantized 0	1	2
	Per cent total solids[1]		
	% - range	% - range	% - range
Conventional	96.9 ± .04	96.5 ± .03	95.9 ± .03
I	97.0 ± .06	96.7 ± .02	96.6 ± .10
II	97.1 ± .05	97.0 ± .04	96.8 ± .06
III	96.8 ± .10	96.6 ± .07	96.4 ± .05
IV	96.8 ± .10	96.3 ± .05	96.0 ± .09

[1]Each figure is the mean value from 3 samples

TABLE 3. Solubility index of egg samples spray dried and treated by different procedures

Spray drying method	Number of times instantized 0	1	2
	ml of precipitate[1]		
	ml - range	ml - range	ml - range
Conventional	.9 ± .1	.7 ± .1	.8 ± .1
I	1.7 ± .1	1.1 ± .1	1.0 ± .1
II	1.5 ± .1	.9 ± .1	.9 ± .1
III	1.6 ± .1	1.0 ± .1	.9 ± .1
IV	1.2 ± .1	1.2 ± .1	1.0 ± .1

[1]Each figure is the mean value from 3 samples

products were instantized. The non-instantized low nitrogen foam spray dried egg products (spray drying methods I and III) were slightly more soluble than the high nitrogen egg products of the same nozzle size (spray drying methods II and IV).

pH

Table 4 shows the foam spray dried products usually had a slightly higher pH than the conventional spray dried products. There was also a tendency for pH to decrease slightly when the egg powder had been instantized. None of the egg powders showed an increase in pH after the whole egg powders had been instantized.

Dispersibility

The foam spray dried egg products usually showed a slight increase in dispersibility over the conventional spray dried egg products (Table 5). The instantized whole egg products for all spray drying methods had a lower dispersibility than the non-instantized egg products. The second instantizing treatment did not appear to affect dispersibility.

Bulk Density

A very marked difference in bulk density was noted between the conventional spray dried and the foam spray dried egg products as shown in Table 6, with the foam spray

TABLE 4. pH of egg samples spray dried and treated by different procedures

Spray drying method	Number of times instantized 0	1	2
	pH		
Conventional	8.6	8.5	8.6
I	8.8	8.6	8.6
II	8.8	8.4	8.5
III	8.8	8.7	8.6
IV	8.8	8.8	8.8

TABLE 5. Dispersibility of egg samples spray dried and treated by different procedures

Spray drying method	Number of times instantized		
	0	1	2
	Per cent dispersed[1]		
	% - range	% - range	% - range
Conventional	93.5 ± 0.9	92.9 ± 0.3	92.4 ± 0.8
I	96.1 ± 1.0	94.7 ± 0.9	95.6 ± 0.9
II	97.0 ± 1.0	94.3 ± 1.0	95.4 ± 0.5
III	96.3 ± 1.2	94.2 ± 0.9	92.0 ± 1.0
IV	96.6 ± 1.0	96.1 ± 0.9	92.5 ± 0.2

[1]Each figure is the mean value from 3 samples

TABLE 6. Bulk density of egg samples spray dried and treated by different procedures

Spray drying method	Number of times instantized 0	1	2
	gram/ml[1]		
	g/ml - range	g/ml - range	g/ml - range
Conventional	.27 ± .006	.30 ± .003	.31 ± .005
I	.12 ± .002	.12 ± .003	.12 ± .003
II	.11 ± .002	.13 ± .005	.14 ± .005
III	.13 ± .005	.14 ± .005	.14 ± .005
IV	.09 ± .004	.10 ± .002	.10 ± .002

[1]Each figure is the mean value from 3 samples

dried product having a much lower bulk density. All spray dried treatments increased in bulk density when the products were instantized. The treatment resulting in the lowest bulk density was that in which high nitrogen and a 0.0292 inch orifice opening was used (spray drying method IV). The products foam dried under low nitrogen exhibited a slightly higher bulk density than those dried under high nitrogen and using either nozzle size.

Filtration Rate

Preliminary observations indicated considerable differences in filtration times between samples. Actual rates, as measured by the time required for the first 10 ml of filtrate to pass through the filter paper in the solubility test, indicated great differences among the samples as shown in Table 7. The filtration times varied markedly from 7 to 164 minutes. The shortest times were noted when the non-instantized egg products were filtered. The four foam spray dried egg treatments had filtration times of about 10 minutes in comparison with an average of 68 minutes for the conventional spray dried egg product. The filtration times for the foam spray dried instantized egg products increased up to 1100 per cent over the corresponding non-instantized foam spray dried egg powder. The greatest increases were recorded for the low nitrogen samples (spray drying methods I and III). Instantizing twice appeared to further increase the filtration times for all spray drying methods. The

TABLE 7. Time to collect 10 ml filtrate of egg samples spray dried and treated by different procedures

Spray drying method	Number of times instantized 0	1	2
	Minutes[1]		
	Min - range	Min - range	Min - range
Conventional	68 ± 5	78 ± 7	81 ± 7
I	10 ± 1	95 ± 8	150 ± 10
II	10 ± 1	45 ± 4	54 ± 5
III	10 ± 2	124 ± 10	164 ± 13
IV	7 ± 1	43 ± 5	72 ± 6

[1]Each figure is the mean value from 3 samples

smallest per cent increase in the filtration time when comparing the instantized products with the non-instantized egg products was found in the conventional spray dried egg products.

Particle Size

Particle sizes of the dried egg products, as calculated from the Coulter Counter data, were categorized as follows: weight per cent 1) 90 microns and above, 2) between 60 and 89 microns, 3) between 30 and 59 microns and 4) less than 30 microns. The majority of the conventional spray dried product measured in the 30-59 micron range with very little of the product above 90 microns as is shown in Table 8. When the whole eggs were foam spray dried there was a noticeable decrease in the 30-59 micron range with the increase coming in the above 60 micron range. That portion of the product measuring less than 30 microns did not vary greatly due to treatment. Instantizing did not appear to affect the particle size distribution in any of the spray dried products obtained in this study, thus it appears little, if any, instantizing (agglomeration) took place.

Observed Dispersibility

The percentage of foam spray dried non-instantized egg products dispersed (as measured by this method) was higher than that of the instantized foam spray dried egg

TABLE 8. Particle size distribution of egg samples spray dried and treated by different procedures

Spray drying method	Number of times instantized 0	1	2
	Weight per cent less than 30 microns[1]		
	Wt.% - range	Wt.% - range	Wt.% - range
Conventional	12 ± 1	14 ± 1	16 ± 1
I	14 ± 1	15 ± 1	14 ± 1
II	10 ± 1	15 ± 1	11 ± 1
III	9 ± 1	13 ± 1	9 ± 1
IV	11 ± 1	12 ± 1	9 ± 1
	Weight per cent from 30-59 microns[1]		
Conventional	69 ± 2	68 ± 2	65 ± 2
I	39 ± 1	37 ± 1	39 ± 1
II	37 ± 1	44 ± 1	41 ± 1
III	40 ± 2	38 ± 1	38 ± 1
IV	37 ± 1	37 ± 1	33 ± 1
	Weight per cent from 60-89 microns[1]		
Conventional	18 ± 1	16 ± 1	15 ± 1
I	30 ± 1	31 ± 1	29 ± 1
II	34 ± 1	27 ± 1	30 ± 1
III	37 ± 1	31 ± 1	33 ± 1
IV	37 ± 1	33 ± 1	35 ± 1
	Weight per cent 90 microns and above[1]		
Conventional	1 ± [2]	2 ± [2]	4 ± [2]
I	17 ± 1	17 ± 1	18 ± 1
II	19 ± 1	14 ± 1	18 ± 1
III	14 ± 1	17 ± 1	20 ± 1
IV	15 ± 1	18 ± 1	23 ± 1

[1] Each figure is the mean value from 3 samples

[2] Less than 1 per cent

products. A few lumps of the instantized dried egg products remained on the surface of the water after stirring, but these lumps or clusters of egg particles became dispersed in the solution when they were stirred again after standing several minutes.

The conventional spray dried egg products sank the fastest with the foam spray dried non-instantized egg powders second but much slower than the conventional spray dried egg powders. At the end of 4 hours, nearly all of the conventional spray dried egg product had sunk below the surface of the water. Dried egg from all foam spray drying methods except for method III showed the non-instantized powder with greater sinkability properties than the instantized foam spray dried egg powders. Product from spray drying method III appeared to have the same sinkability characteristics regardless of the number of times instantized.

DISCUSSION

One of the major problems encountered in handling dried egg products is related to their lack of "flowability." The treatments used in this study (foam spray drying and instantizing) were believed to affect this product characteristic.

Foam spray drying has been reported as increasing particle size, which should improve flowing properties of the dried product. In this study, the desired flowability was not achieved as was shown by a failure to sieve the whole egg powder using the RoTap Shaker.

It was felt that foam spray drying and instantizing should increase particle size. However, in this study instantizing whole egg powder under the conditions used did not appear to increase particle size, as shown by the results from the Coulter Counter analysis. Perhaps the conditions for instantizing whole egg powder should differ from the conditions used for milk powders. In view of the observation that the total solids content decreased only slightly, perhaps more steam or a wetting agent should be tried, or the colloidal silica gel method as suggested by Forsythe (1964).

The decrease in total solids after instantizing was not as great as had been reported by Mori and Hedrick (1965) using dry milk solids. It is possible the higher fat content of the spray dried whole egg product did not allow as much moisture to penetrate the egg particles in comparison with the milk powders. If the egg particles did not become very wettable this could account for the little difference in particle size before and after instantizing.

The reason the solubility of egg powder was decreased after instantizing as shown in spray drying methods I, II and III, is not known. Comparisons among the total solids content, particle size distribution, bulk density and dispersibility do not appear to provide an answer. The decrease in pH is more apparent between the non-instantized and instantized products in all the spray drying methods although the differences are slight.

The great variation in time required to collect the first 10 ml of filtrate in the solubility study is apparently not related to other results, including the egg powder solubility. There did not appear to be any clumps of particles remaining on the filter paper after filtering.

The results in the dispersibility tests were relatively high, although Miller _et al_. (1959) reported results greater than 95 per cent dispersed using a slightly different method and only using conventional spray dried egg powders. Downs (1966) reported that on several occasions results were obtained in excess of 100 per cent. Mori

(1964) reported a maximum of 48 per cent dispersibility when testing instantized milk powders using another method.

The decrease in bulk density of products foam spray dried was expected, since the nitrogen was incorporated into the liquid whole egg before drying. The increase in bulk density after instantizing was also expected since total solids content normally decreases when the egg powder is instantized.

The instantizing procedure used in this experiment following the spray drying operation for whole eggs does not appear to be worth-while, since both solubility and dispersibility decreased. Instantizing the whole egg powder had little effect on the particle size distribution, bulk density or the apparent flowability of the egg powder.

Based on review of all data obtained, foam spray dried whole egg powder has increased solubility, larger particles, decreased bulk density and is slightly more dispersible than the conventional spray dried whole egg powder.

It would also appear that a powder with a high fat content such as whole egg powder, needs further research before the desired flowability characteristics can be improved without the addition of such products as a colloidal silica gel preparation.

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