

DAIRY PIPELINE

A Technical Resource for Dairy Manufacturers

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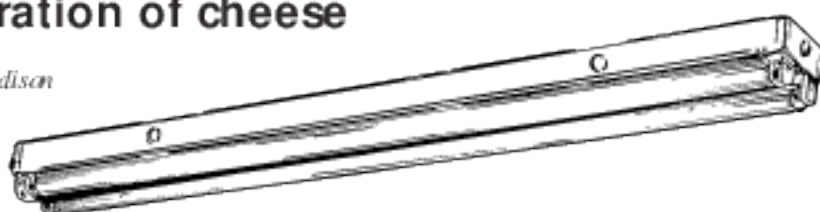
Getting the pink out Controlling pink discoloration of cheese

W.L. Wendorff, Dept. of Food Science, UW—Madison

Extract of annatto seed, from the annatto tree, supplies the yellow-orange color to cheese. These annatto-colored cheeses are susceptible to pink discoloration when stored under high intensity fluorescent lights in retail display cases. Many questions arise concerning pinking of annatto-colored cheeses, including: where does the pink color come from, what factors contribute to the potential for pink discoloration, and how can we control the pinking of annatto-colored cheeses?

Origin of pink discoloration

Previous researchers (1,2,3) have reported that high intensity fluorescent light affects color stability and causes lipid oxidation in annatto-colored cheeses. UW researchers (3) have reported that pink discoloration can appear in cheddar and colby cheese after only 6-8 hours of fluorescent light exposure. A rapid loss of the yellow component of the annatto coloring the cheese produces this pink color at the cheese surface. After an extended period under the lights the red component of the annatto color is also lost, but at a slower rate. Thus a pink color dominates before progressing to a bleached-out appearance. In a survey of Madison, Wisconsin supermarket dairy cases, we found fluorescent light intensities ranging from 140 to 640 footcandles, with an average intensity of 300 footcandles. In our research studies (3), we held cheeses under a light intensity of 250 footcandles and did find, in some cases, that pinking occurred within two days at that intensity.



Barnicot (4) reported that sulfhydryl compounds present in aged cheddar cheese were responsible for oxidation of the annatto colorant, which resulted in pink discoloration. On the other hand, Govindarajan and Morris (2) reported that the pink compound formed was not the result of oxidation of norbixin from annatto, but that hydrogen sulfide was involved in the formation of a pink colored, micro-fine precipitate of norbixin. In our studies (5), we did not determine the specific chemical reaction taking place to form the pink or red compound but we did observe that formation of the pink discoloration from annatto colorant coincides with the development of lipid oxidation in the affected cheese.

Factors affecting pink discoloration

We have evaluated the effect of light type and intensity, storage temperature, exposure time, cheese composition, and age and source of colorant on stability of annatto colorants in cheese. Following is a summary of the results.

Light type and intensity

Cheeses stored under cool white fluorescent lighting showed a faster rate of pinking than soft white lighting, although both types of light did induce pink discoloration. Increased light intensity meant faster development of pink color over the first 2 days of exposure, but it did not differ after longer storage.

Storage temperature and time

Samples stored at 47°F had a faster rate of pinking than those stored at 36°F. However, no

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significant differences in color stability occurred between the two storage temperatures when stored beyond 2 days.

Cheese composition

Cheese pH is a major factor affecting pink discoloration in annatto-colored cheeses. At pH 5.4, the red and yellow components of annatto were reduced at a comparable rate and the cheese developed a bleached appearance under fluorescent lighting. However, at pH 4.8 and 5.1, the yellow component decreased at a very rapid rate while the red component decreased at a slower rate. The result was a very intense pink color. Full fat cheeses produced a more intense pink color than reduced fat cheeses during the first 7 days of storage.

Source and age of colorant

Some differences were observed in color stabilities of single strength annatto colorants produced from different sources of annatto seeds. As with any biological crop, seasonal, geographic, and climatic conditions may all influence color stabilities of annatto. Colorant manufacturers monitor and blend sources to produce uniform colorants from available seeds. In our studies, older annatto colorants produce greater pink discoloration.

Influence of packaging on pinking

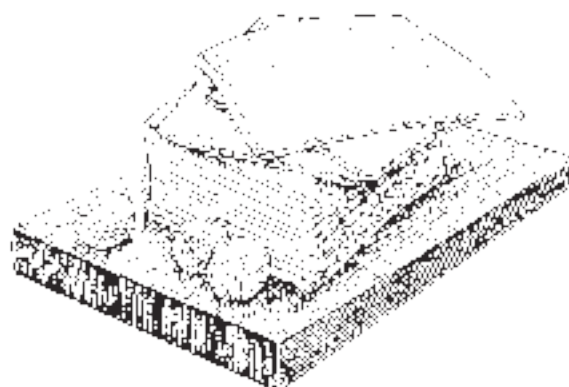
We evaluated packaging systems, packaging films and light blocking agents to determine if any of these factors could eliminate or reduce the pinking problem in annatto-colored cheeses.

Packaging systems and films

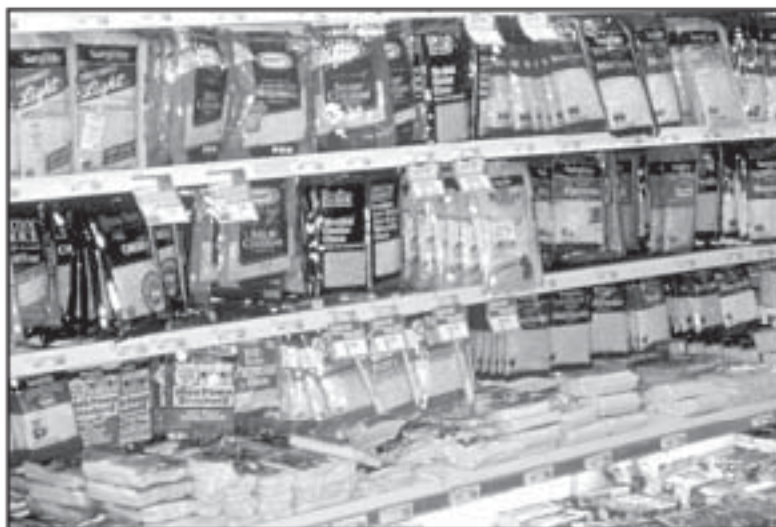
After evaluating modified atmospheric packaging (MAP), we found that films with higher oxygen transmission rates (OTR) produced pink discoloration in cheddar cheese before the cheese packaged in films with lower OTRs. Discoloration was first observed around the cracks and slits on the surface of cheese and in the head space at the end of the packages, where oxygen was

most likely available. Films with lower OTRs had less oxidized flavor after 7 days. However, after 2 days of storage under fluorescent lighting all cheeses had oxidized flavor.

With comparable OTR in packaging films, vacuum packaged cheeses initially retained the yellow component of annatto better than MAP cheeses. However, the reduced conditions present in vacuum packaged cheeses tended to produce a more intense pink color after 7 days. With vacuum packaging, color stability of cheese samples displayed under cool white and soft white light was not significantly different.



Cheese pH is a major factor affecting pink discoloration in annatto-colored cheeses.



Light blocking agents

Tube guards with UV-blocking agent did not prevent light-induced pink discoloration. Perhaps near-visible wavelength light catalyzes pink discoloration. Transparent colored films (red, sunburst, and burnt-orange) did not retard pink discoloration, but the burnt-orange film did reduce lipid oxidation in vacuum packaged cheeses stored for more than 7 days under fluorescent light. Aluminum laminated film provided the greatest protection against pink discoloration in vacuum packaged cheeses.

Preventing pinking in annatto colored cheeses

The high intensity fluorescent lighting used in retail dairy cases can seriously affect the quality of dairy products. For example, oxidized flavors developing in fluid milk products has been extensively documented. Now we know that high intensity fluorescent lighting can cause the loss of color components from the annatto colorant in cheese, producing a pink discoloration in those cheeses. Along with the pink discoloration, an objectionable oxidized flavor also develops. To reduce the potential for pink discoloration in annatto-colored cheeses, cheesemakers should avoid using old colorants and select appropriate packaging with a low oxygen transmission rate (OTR). Light blocking film, e.g., aluminum laminated film, will provide good protection against potential pinking but at a slightly higher cost than transparent packaging films.

At the retail display case, the intensity of fluorescent lighting should be held to no more than 160-200 footcandles at the exposed surface of the cheese. Island display cases, with overhead fluorescent lighting, are ideal for displaying colored cheeses. In many horizontal display cases, we found fluorescent bulbs within 6 inches of the product emitting 640 footcandles on the cheese surface. Not only did this drive the formation of pink discoloration on the cheese, but the product temperature of 60-65°F also contributed significantly to the breakdown of the body and texture and the development of off-flavors. In our studies, we found about 2 to 5% of the top or front pieces of cheddar or colby cheeses in supermarket retail display cases showed pink discoloration and the potential for oxidized flavor defects. Consumer rejection of the discolored cheese alone could represent a loss of over \$30 million per year to the dairy industry.

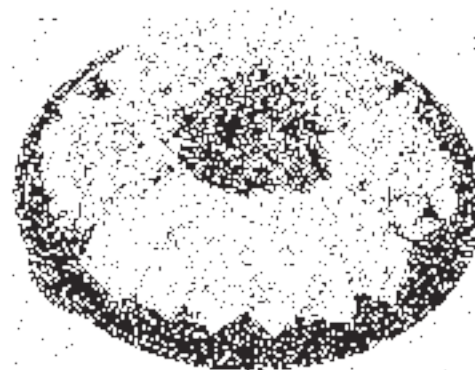
In summary, cheese manufacturers can produce high quality annatto-colored cheeses and package those in low OTR barrier films to extend shelf-life. But manufacturers must also work with their distributors, brokers and retailers to make sure they understand the correct display lighting and handling procedures for cheeses so that the consumer is getting a quality product time after time.



References

1. Moir, G.M. 1933. Discoloration in New Zealand Cheddar cheese. Muddy, bleached and pink defects. II. Biochemical investigations. *J. Dairy Res.* 4: 238-245.
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3. Hong, C.M., W.L. Wendorff, and R.L. Bradley, Jr. 1995. Factors affecting light-induced pink discoloration of annatto-colored cheese. *J. Food Sci.* 60: 94-97.
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Research Update

Black spots in aged cheddar—all you need is milk and time

Researchers at the Wisconsin Center for Dairy Research and the UW-Madison Department of Food Science have fielded numerous inquiries about a mysterious black spot defect (BSD) in cheese, specifically, in aged cheddar cheese. The scientists can't make the spots disappear, but Associate Professor Scott Rankin can tell you what they are and how they got there.

Rankin's first step was to determine the composition of the black spots. Exactly what were they made of? Isolating the cause of the black spots proved to be difficult because the substance did not dissolve or diffuse easily. Rankin did discover that the BSD pigment dissolves readily in nitric acid, suggesting an inorganic salt origin. Next, inductively coupled plasma mass spectroscopy was used to screen many different elements, focusing on finding culprits like the metalsalts and oxides that might be found on food grade processing equipment.

The spectroscopy identified chromium, copper, iron, nickel and bismuth in BSD areas. When the cheese near the black spot defect was assayed the same way, the scientists found small increases in the same elements—except for bismuth. Bismuth concentrations in the BSD region were about three orders of magnitude greater than cheese without black spots.

Early anecdotal reports suggested that an intra-mammary teat sealant (ITS) might be part of the black spot problem. This particular ITS, OrbesealTM, contains aluminum stearate, silicone dioxide, mineral oil and 65% bismuth subnitrate. To confirm the role of bismuth subnitrate in the BSD the scientists made cheese with known amounts of teat sealant components. They demonstrated that bismuth subnitrate, in the presence of H₂S, hydrogen sulfide gas, produces black pigmentation.

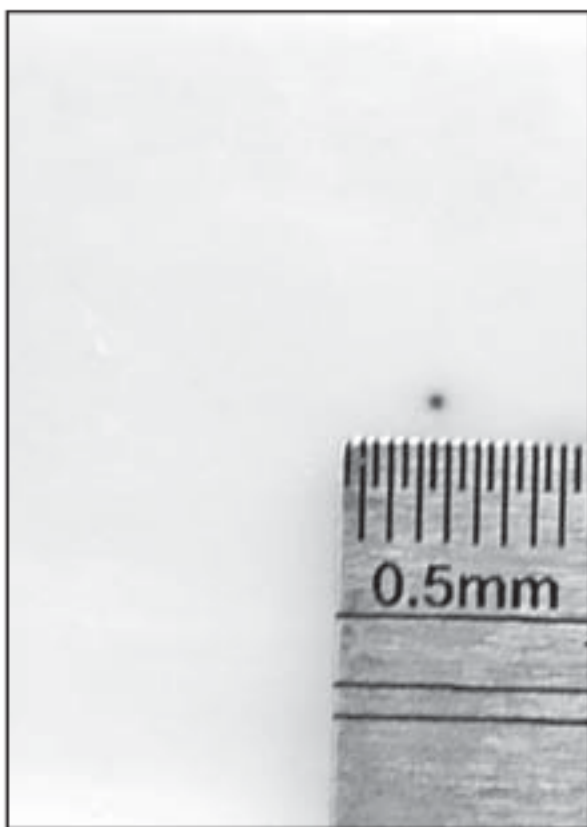
Teat sealant reappears

So how does a supposedly inert, and highly effective, teat sealant reappear months later in cheddar cheese? Rankin thinks that the bismuth subnitrate in the sealant is carried in milk to the cheese vat. All is well until H₂S is produced during the cheese aging process. Then you get a reaction between bismuth subnitrate and H₂S, which produces bismuth III sulfide, the likely culprit in the BSD. (See reaction below.)

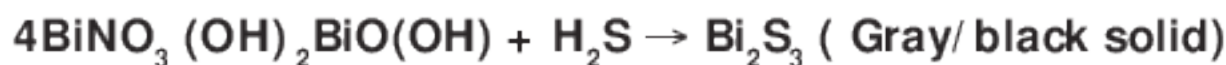
Of course, the path from mild cheddar to sharp cheddar is rather complex. But we do know that H₂S, considered by some scientists to be a valued component of aged cheddar flavor, is the product of microbial, enzymatic, and co-factor reactions with sulfur containing amino acids, like cysteine. Thus, H₂S is a natural byproduct of cheese aging.

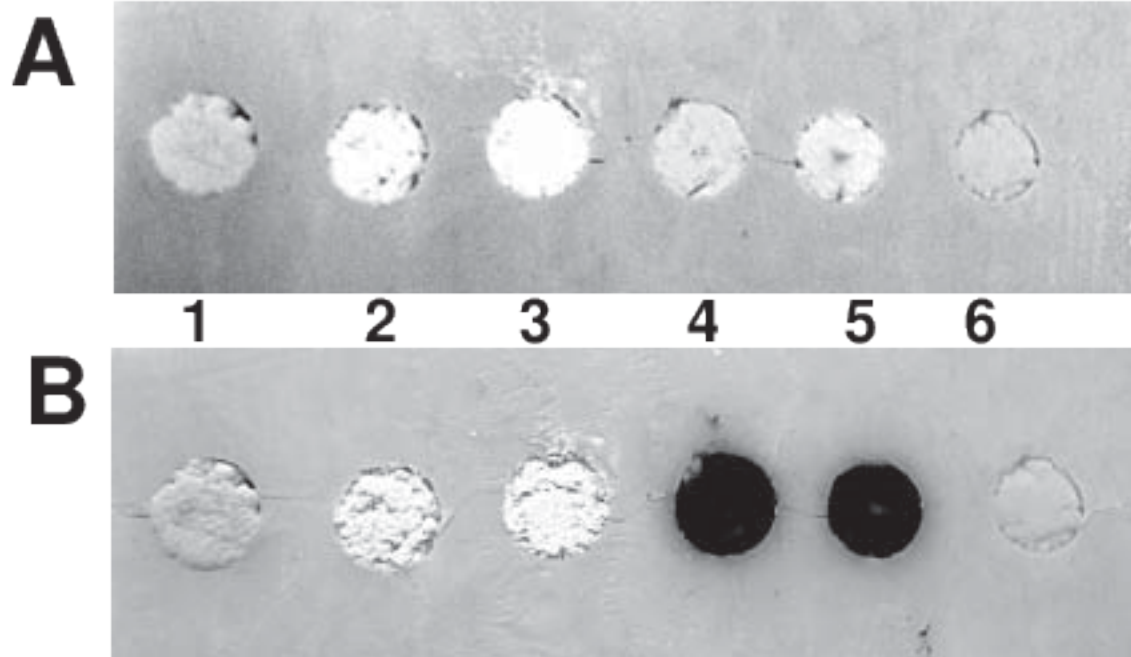
Possible solutions

Some cheese companies have banned the use of OrbesealTM. Other solutions include more training for the herdsmen who apply the teat sealant, as well as improving protocols for cleaning, particularly plastic parts which the teat sealant sticks to rather well. Dairy field reps also recommend that producers who use OrbesealTM carefully strip any remnants of the treatment out of the teats and refrain from adding the colostrum to the milk supply. It is also important to change filters daily, not just wash them, but use a new one.



Black spot defect in aged cheddar cheese





Images of sites made by blending cheese with ITS components before (A) and after (B) exposure to either hydrogen sulfide gas or its natural equivalent, volatiles from aged cheddar cheese. Sites 4 and 5 were made with bismuth subnitrate and intact ITS, respectively.

On the cheesemaker side, remember that Orbeseal™ has not been shown to affect cheeses before 3 to 6 months and, also H_2S is part of the chemical reaction. Thus mozzarella, colby, monterey jack and similar cheeses will probably not have the black spot defect, even if Orbeseal™ is in the milk.

Rankin suggests that the BSD will not dissolve or diffuse out of aged cheddar cheese. However, some cheese plants have installed clarifiers that can pull the bismuth out of the milk, but that is an expensive solution.

It is difficult to quantify the BSD problem. The lag time of development clouds the issue and so does the fact that the black spots don't just form on the cheese surface, they can be found throughout the cheese. By all accounts, Orbeseal™ is an effective teat sealant that can reduce mastitis. But is it worth it to an aged cheddar cheese manufacturer? 

It is difficult to quantify the BSD problem. The lag time of development clouds the issue and so does the fact that the black spots don't just form on the cheese surface, they can be found throughout the cheese.

Save money by separating for higher fat cream

By R.L. Bradley and D.A. Sommer, Center for Dairy Research

We are facing high fuel prices today and all signs point to only limited and/or temporary abatement in the near future. Perhaps now is the time for dairy plant operators to consider the best way to reduce trucking costs. For example, you know what it costs to haul cream per loaded mile. Do the calculation for 35% cream, then recalculate for 45% cream. There should be, approximately, a 22% savings. In addition, cheesemakers can accrue other benefits besides fuel savings since more milk solids-not-fat (SNF) will be retained in the plant for cheesemaking and fluid milk plants will have more skim milk.

While higher fat cream and more SNF in the dairy plant may be an old subject, there are some guidelines that will influence success. First, the fat test of the cream should definitely be below 50%. If the fat test is higher than 50%, then the greater viscosity at less than 45°F causes problems. With higher viscosity comes handling difficulties, slower cooling, pumping problems, persistent foam from air incorporation and more cream left in the storage tank at pump out. Subsequently, when you add a hot water rinsing of the cream tank to the pumped out cream you reduce fat and SNF contents per unit volume. Thus, you are limiting the net reduction of trucking cost, as you would expect.

Better at 45% fat

Butter plants buying whey cream have common as well as individual considerations. While the viscosity of whey cream is less than sweet cream, you should use 50% as a maximum fat content for both. Blending the < 50% fat whey cream into sweet cream is easier; the rate of cooling, foam stability, and pumping is improved. In addition, rinsing from storage and tankers will be easier and usually needs less steam or hot water. All of these factors work out better at 45% fat.

Other concerns are titratable acidity, free fatty acids, i.e., Acid Degree Value (ADV) (rancidity), the number of days the whey cream has been used to standardize milk for cheesemaking, and the extent of pumping with high speed centrifugal pumps.

The latter two concerns could contribute to production of globular fat (greater fat losses to buttermilk) and fat that does not churn well because the fat globule membrane is missing or greatly damaged.

At the butter plant

At the butter plant, a good, well-trained churn operator can minimize fat losses to buttermilk using a higher fat cream. However, most continuous churns operate ideally between 38 and 42% fat. While it is easy to suggest diluting high fat cream to a lower fat content with lower fat cream, it is not always that easy to do. Success depends on the diameter of the blending silo and controlling the agitation. Since most narrow diameter silos do not mix well top to bottom, there will be a fat percentage gradient which requires an alert continuous churn operator and quick response from the laboratory during churning. With the appropriate engineering you could draw from two silos continuously by using two flow meters and two PD pumps. You will need this type of set-up to prevent the silo with the greater head pressure (volume) filling the silo with lesser head pressure through the discharge valves.

If a lot of hot water was used to rinse the cream tank, then the fat content of the entire load will be reduced, as well as the percentage of SNF in the resulting buttermilk. Condensing costs for buttermilk will increase.

Retaining more skim solids adds additional value to your cheese through increased yield. This is a win-win solution all the way around.

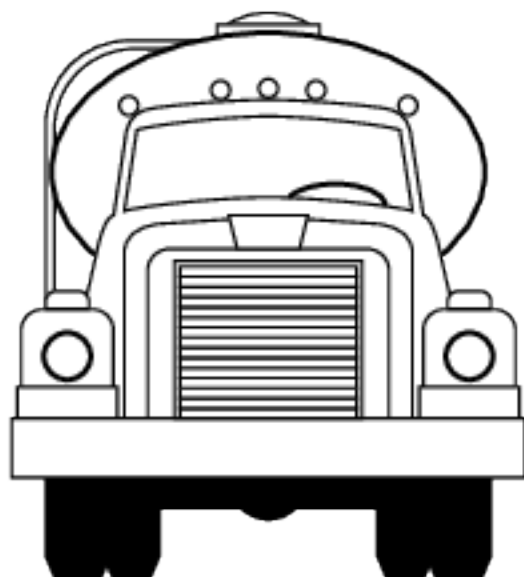
Value of dairy products manufactured from 1 million lbs of raw milk with 5000 gallons cream removed^d

Product manufactured ^c	Value, 35% cream	Value, 45% cream	Savings/Day
Mozzarella	\$129,330.89	\$129,884.82	\$553.93
Cheddar	\$142,927.12	\$143,132.83	\$205.71
Whey powder	————	————	\$102.00 ^{ab}
Non fat dry milk	————	————	\$529.76 ^{ab}
^a less costs of condensing and drying			
^b 500 gallons available by concentrating fat			
^c calculations used mozzarella and cheddar at \$1.40/lb, NDM at \$1.40/lb and dry whey at \$.40/lb.			
^d calculations available on request			

Dairy plant personnel need to be cautious initially to generate and truck higher fat sweet cream or whey cream successfully. First of all, the separator must be correctly sized. If it is starved, you will produce foam. From here, one problem leads to another since foam has insulating properties and the cream won't cool rapidly. This may lead to detectible hydrolytic rancidity in sweet cream. Even if it is not detectible by taste, there will certainly be an elevation of the ADV. Many butter plants reject cream above a value of 1.0 to 1.1 ADV. This is based on separation on the hot side of the regenerator where sweet cream at separation is only heat treated. Also, to control foam generation, be certain that there are no air leaks before the separator. A common source of

air is the seal on the back plate of the separator stuffing pump; check this. Further, with hot, heat-treated cream coming from the separator, the cool down to less than 45°F must be rapid. Use in-line tubular cooling to assure this and do not rely on the refrigeration at the holding tank for cooling. A correctly sized separator stuffed by a centrifugal pump controlled by a variable frequency drive will do minimal damage to the fat globule membrane. Thus, any effect on the ADV, i.e., lipase activity, will be minimal.

Consider also that the price of cream should have a value for the SNF included. Thus, if the dairy ships a higher fat cream resulting in more retained SNF in the dairy plant the buttermaker will not be losing buttermilk solids and value. And don't forget that retaining more skim solids adds additional value to your cheese through increased yield. This is a win-win solution all the way around.



Curd Clinic

Curd Clinic Doctor for this issue is Marianne Smukowski, Safety/Quality Applications Coordinator, CDR

Q. I know that I need to keep records of my suppliers and distributors, but I am also wondering how to use this as an opportunity to improve my quality assurance program overall. Do you have any suggestions?



A. You are right, the Public Health Security and Bioterrorism Preparedness and Response Act of 2002 requires more recordkeeping by manufacturers, processors, packers, and transporters. Specifically, food processors and manufacturers need to keep records of immediate previous sources and immediate subsequent recipients of food. Popularly referred to as “one up, one down,” this directive allows the FDA to track potential problems in the food supply. Since you have to do this anyway, I applaud your willingness to see it as an opportunity to improve your Quality Assurance program.

The new regulations are a good excuse to have a conversation with your suppliers and customers. Think of it as a chance to develop a closer, more cooperative relationship. For example, have you ever sat down and discussed exactly which attributes of an ingredient are most important to your company? Have you let them know that you definitely want to know about any formulation changes?

Many processing plants have been audited, but have you considered auditing your suppliers? A third party audit can assure you of your supplier's high quality. Do you regularly request a Supplier Guarantee? Does a Certificate of Analysis come with the products you order? Have you ever tried confirming a COA with your own analysis? Occasional random samples are recommended. These are simple steps but they prove you are emphasizing quality and they help you do it.

You should be doing a mock recall twice a year. When you do a mock recall, do you take the simple route and focus on your finished product? Try taking it one step further and do a mock recall on an ingredient. For example, if you make ice cream set up your recall to trace the pecans in butter pecan. Or try tracing the annatto in your butter or the salt in your cheese. A mock recall of ingredients is more work, but it is also a better test of the process.

Do you retain samples of your outgoing product? Many processing plants do; these samples can be very useful if you ever have to recall product or investigate complaints.

I have included a few ideas that you can use to improve your quality assurance program. If you have any questions about the Bioterrorism Act and how it affects your plant please feel free to contact me.

e-mail: msmuk@cdr.wisc.edu

Phone: (608) 265-6345

What your records should include

Here at CDR, we use rather simple forms to track both shipping and receiving. Our receiving log lists the source and includes the address and phone number. In addition, we include the brand and variety, lot number and expiration date and the quantity. Section 306 of the Bioterrorism Act explicitly limits the retention of records to two years or less. If a facility holds food for longer than two years, it may wish to retain records of receipt for more than two years as a matter of business practice. These records could be helpful to both the facility and FDA in the event of a trace back or trace forward investigation.

More information at the FDA Website

The U.S. Food and Drug Administration (FDA) maintains a massive website detailing everything you need to know about the Bioterrorism Legislation. Here is an example.

What records must be established and maintained by non-transporters of food? For non-transporters, i.e., persons who own food or who hold, manufacture, process, pack, import, receive, or distribute food for purposes other than transportation, the records have to:

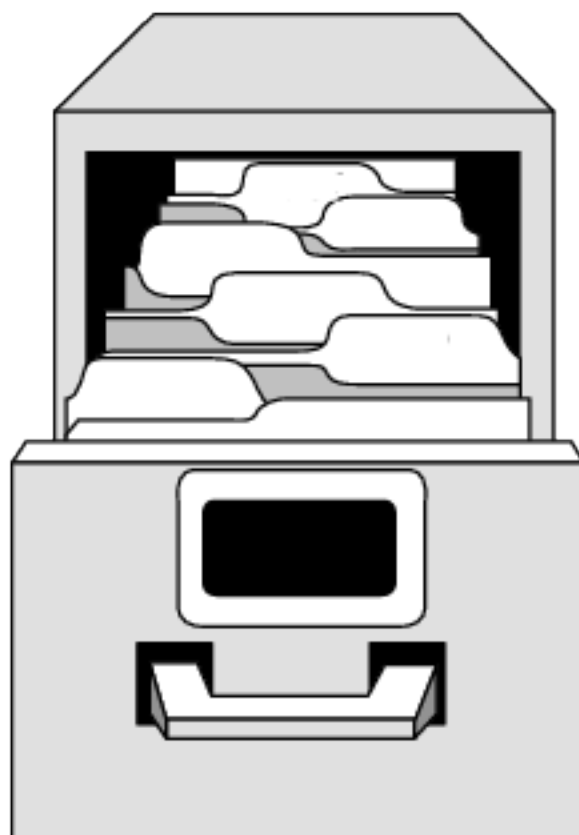
1. Identify the immediate non-transporter previous sources, whether foreign or domestic, of all foods received, including the name of the firm; address; telephone number; fax number and e-mail address, if available; type of food, including brand name and specific variety (e.g., Brand X Cheddar Cheese, not just cheese; romaine lettuce, not just lettuce); date received; quantity and type of packaging (e.g., 12 oz. bottles); and identify the immediate transporter previous sources including the name, address, telephone number—and, if available, fax number and e-mail address. Persons who manufacture, process or pack food also must include lot or code number or other identifier if the information exists.

2. Identify the immediate non-transporter subsequent recipients of all foods released, including the name of the firm; address; telephone number; fax number and e-mail address, if available; type of food, including brand name and specific variety; date released; quantity and type of packaging; and identify the immediate transporter subsequent recipients, including the name, address, telephone number—and, if available, fax number and e-mail address. Persons who manufacture, process or pack food also must include lot or code number or other identifier if the information exists. The records must include information that is reasonably available to identify the specific source of each ingredient that was used to make every lot of finished product.

<http://www.cfsan.fda.gov/~dms/fsbtac23.html>

COA vs Supplier Guarantee

What is the difference between a Supplier Guarantee and a Certificate of Analysis (COA)? The COA is essentially a spot check, giving you a result from a tested lot. A Supplier Guarantee is more specific, assuring you about a particular item over a specified unit of time. For example, if you really need medium cheddar cheese with a specified moisture content then a Supplier Guarantee will back that up.



News from CDR

CDR Authors

A technical paper "Storage Temperatures Necessary to Maintain Cheese Safety," coauthored by CDR Director Rusty Bishop and Dairy Safety & Quality Coordinator Marianne Smukowski, was featured in the October issue of Food Protection Trends magazine. For more information, contact Marianne Smukowski at msmuk@cdr.wisc.edu.

Regional workshops

NEW! CDR will be offering day-long, regional workshops in three locations around Wisconsin in October. The focus, "Cheese Health and Wellness" and "Cheese Yield and Standardization". Watch for more details later this spring.

Design your own affinage system

Interested in learning more about affinage, the craft of aging and maturing cheese in a controlled humidity and temperature environment, and the opportunities that exist? The UW-Madison Department of Food Science and the WI Center for Dairy Research will be conducting a two-day Master's Short Course, August 21-22. The first day will highlight the European tradition, explore systems being used in the US today, and walk you through what you need to design your own affinage system. During day two, you will learn about cheese ripening conditions, packaging, and quality as well as regulatory issues. For more information visit www.cdr.wisc.edu and click on Courses and Events.



Sports Recovery Drink

The next time you visit Babcock Hall you might want to try a new sports drink developed at the Wisconsin Center for Dairy Research. The beverage is sold in the Dairy Store, located on the first floor of Babcock Hall.

The Dairy Ingredients group at CDR developed this "sports drink" for athletes at the University of Wisconsin-Madison. Not only does it taste good, but it is designed for athletes who want to build muscle as they work out. It also helps athletes recover from workouts faster while preserving their muscle mass.

Amino acids are often referred to as the building blocks of protein. And among the amino acids, branched chain amino acids (BCAA) are particularly useful for athletes. Skeletal muscles that power runners, bikers and swimmers can take up the BCAAs directly from the bloodstream, unlike other amino acids that are only available after processing by the liver.

Whey protein is a fabulous source of branched chain amino acids, a fact that has propelled the growth of whey proteins in the sports world. You can find it in bars, beverages, powders and supplements consumed by football players, marathon runners, swimmers and skiers.





KEEP REFRIGERATED

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with whey protein

8 FL. OZ. (HALF PINT) 236 ML

Nutrition Facts

Serv. Size: 1 Container Amount Per Serving Cal 170

Total Fat 2.0g (4% DV) Sat Fat 0g (0% DV)

Total Carb 28g (11% DV) Fiber 0g (0% DV)

Sodium 20mg (4% DV) Protein 9g (18% DV)

Ingredients: WATER, DEXTROSE, APPLE JUICE CONCENTRATE, WHEY PROTEIN CONCENTRATE, PHOSPHATE, PHOSPHORIC ACID, NATURAL ORANGE FLAVOR, SUCRALOSE, YELLOW 6

Mark your calendar and make a plan

The Wisconsin Cheese Industry Conference is set for April 18-19, 2007 in La Crosse, Wisconsin. CDR is hosting two seminars on Thursday, April 19th. The morning session will focus on the natural attributes of cheese that make it an ideal vehicle to deliver nutraceuticals. Speakers and their topics include:

Paul Ross, Dairy Product Research Center, Teagasc,
Moorepark Food Research, Ireland

Probiotics in functional cheese and the effect on health—a medical perspective

Mark Johnson, Wisconsin Center for Dairy Research
Lowfat/low salt cheese

Dean Sommer, Wisconsin Center for Dairy Research
Omega three fatty acids and other fortified cheeses

The wrap up—a chance to taste some fortified cheeses made in the European Union and a few from CDR.

The April 19th afternoon session will focus on the unlimited opportunities for using dairy ingredients.

John Lucey, UW—Madison Food Science
Separation processes to enhance the functionality of dairy proteins

Rich Hartel, UW—Madison Food Science
Spray drying delactosed permeate

Kellogg Company, research staff
Opportunities and success with dairy ingredients

Alan Reed, Dairy Management Inc.
New products in the global market



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You can also find the Dairy Pipeline on our website: www.cdr.wisc.edu

Calendar

Jan. 18-19 Producing Safe Dairy Products. River Falls, WI. Call Rane May at (715) 425-3704 for information.

Feb. 6-7 Quality Milk Conference (WI Dairy Field Reps). Madison, WI. Call Scott Rankin at (608) 263-2008.

Feb. 27-28 Wisconsin Process Cheese Short Course. Madison, WI. Call Bill Wendorff at (608) 263-2015 or John Jaeggi at (608) 262-2264 for more details.

Mar. 26-30 Wisconsin Cheese Technology Short Course, Madison, WI. Call Bill Wendorff at (608) 263-2015.

Apr. 18-19 Wisconsin Cheese Industry Conference, La Crosse, WI. For information, call Judy Keller at (608) 828-4550.

Apr. 30-May 2 Cheese Utilization Short Course, Madison, WI. Call Dean Sommer at (608) 265-6469.

May 8 Wisconsin CIP Workshop, Madison, WI. Call Bill Wendorff at (608) 263-2015.

May 9 Dairy HACCP Workshop, Madison, WI. Call Marianne Smukowski at (608) 265-6346.

May 15-16 Applied Dairy Chemistry Short Course, Madison, WI. Call Scott Rankin at (608) 263-2008.



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