CHR. HANSEN

Cheddar Cheese

Second revised edition, March 2002

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Cheddar Cheese

1. Introdution

Cheddar cheese segment

This brochure is one of a series that has been produced to give you an overview of starter culture performance and modern manufacturing technology. It also provides a good insight into the experience and knowledge available to you as a partner of Chr. Hansen. For more than 50 years cheese-makers have turned to us to improve the quality of the food they make for people all over the world.

Our aim has always been to provide excellent products and we are aware that a product is only excellent when it gives the best results. One of the major reasons behind the success of Chr. Hansen's products is the partnership we establish with our customers. A continuing dialog ensures that our customers use the best products for their needs in the best way. This dialog is also a source of inspiration for new developments as the needs and requirements of our customers are the main driving force behind our R&D.

For nearly 130 years Chr. Hansen has worked to help food manufacturers offer high quality products. From the beginnings with rennet, Chr. Hansen has grown into a full-range supplier for the dairy industry. Apart from a complete range of coagulants, the cheese-maker now has far greater flexibility and better control over his processes and products, thanks to Chr. Hansen colors, dairy cultures and enzymes - all from natural sources.

Chr. Hansen bridges the gap between traditional methods and the development and implementation of innovations, allowing people like you to concentrate on what they are best at - making cheese. For more information contact your local sales office or application center, there are more than forty in as many countries throughout the world.

Segment description	Typical examples	Scalding	Texture
Feta types	Feta, White cheese	max 35°C (95°F)	Semi-soft cheeses
Soft cheese types	Camembert, Brie, Argentine Port Salut, Crescenza, Gorgonzola	max 35-40°C (95-104° F)	Soft to semi-soft cheeses
Continental types	Gouda, Edam, Samsoe, aasdammer/ Leerdammer, Saint Paulin, Raclette, Manchego, Prato	35-40°C (95-104° F)	Semi-hard cheeses
Cottage cheese types	Cottage cheese	22-32°C (72-90°F)	Soft fresh cheese
Cheddar types	Cheddar, Territorials, American Cheddar, Monterey Jack, Colby	36-42°C (97-108° F)	Hard cheeses
Pasta filata types	Mozzarella, Pizza cheese, Provolone	36-43°C (97-109° F)	Semi-hard to hard cheeses
Emmenthal types	Emmenthal, Gruyère	max 54°C (129°F)	Hard cheeses
Grana types	Grana, Parmesan, Sbrinz	50-55°C (122-131°F)	Hard cheeses

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2. General characteristics of Cheddar cheese types

The **Cheddar** segment represents the largest cheese segment. It is typified by Cheddar cheese traditionally made in the UK, but now produced worldwide. In appendix 1 other examples of typical cheese types belonging to the **Cheddar** segment are given. This and the following sections introduce typical characteristics, production procedures and the critical elements in the manufacture of these cheese types.

Some of the general characteristics of the segment are listed as follows:

* Fat in dry matter 20-60%
* Water content 34-42%
* Salt content in cheese 1,5-2,5%
* Acidification to allow cheddaring process
* Pressed to obtain a closed rind
* Dry salted after milling prior to press
* Usually vacuum packed or barreled

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3. Chr. Hansen ingredients for manufacture of Cheddar

3.1 Cultures

Primary cultures

Traditionally, starter cultures for production of cheddar cheese have consisted of mesophilic strains. Today, more and more Cheddar is made using mesophilic and thermophilic blends.

Information on the composition and general performance is shown in the table below:

Strain name	Speed of lactic acid production	Citrate fermentation	Composition O culture	Composition RST culture	Composition RSF culture	Homo-fermentative	Hetero-fermentative
Lactococcus lactis subsp. *lactis*	+++	-	+	+	+	+	-
Lactococcus lactis subsp. *cremoris*	+++	-	+	+	+	+	-
Streptococcus thermophilus	+++	-		+	+	+	-
Lactobacilli species	+	-			+	+	-

Typically, starter cultures for Cheddar and Cheddar types are mesophilic strains; homofermentative types that ferment lactose to lactic acid. The Chr. Hansen **O-culture** range contains the two most widely used strains *Lactococcus lactis* subsp. *lactis* and *Lactococcus lactis* subsp. *cremoris*. The selection criteria for these strains are that they should be rapid acidifiers, be phage hardened and produce the correct flavor attributes.

Recent developments in starter technology have made the **RST concept** possible. This involves blending mesophilic and thermophilic strains to take advantage of the scald temperature used in Cheddar manufacture, which is normally > 38°C (> 98°F). This increases the activity of the starter enabling reduced inoculation rates.

The most recent addition to our Cheddar culture product range is RSF cultures. These cultures incorporate flavor enhancing strains and are widely used to differentiate flavor types.

Some Cheddar types require a more open texture and different flavor profile, such as Cheshire. Here in addition to the above strains, heterofermentative strains can be incorporated to ferment citrate.

In addition to these primary acidifying cultures, particularly the latter, it is possible to add secondary cultures that can help differentiate flavor and texture types. Examples of strains used here are ***Lactobacillus helveticus*** and ***Lactobacillus casei.***

The range of cultures, including speed of acidification, eye formation and phage group, are shown in the table on the next page together with product form.

For the production of most Cheddar cheese types, the use of an inoculation rate of either 0.005-0.01% F-DVS or 500u-1000u FD-DVS per 10,000 l milk is recommended.

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2.1.1 Product range primary cultures

Culture name	Phage group	Culture type	Characteristics
R-603/R-703	1	Single strain culture blend *Lactococcus Lactis*.	Medium/high activity
R-604/R-704	1	Citrate negative	No gas production
R-607/R-707	2	Homofermentative	
R-608/R-708	3		
RST-643	4	Mesophilic and Thermophilic blends.	
RST-676/776	4	Citrate negative	High activity
RST-744	5	Homofermentative	No gas production
RST-630	6		
RST-631	7		
RSF-621[1)]	5	Mesophilic and Thermophilic blends.	High activity
RSF-636	6	Homofermentative	No gas production
RSF-637	8	Citrate negative	Improved flavor
RSF-638	9	[1)] Citrate positive	[1)] Low gas production

NB. Culture in rotation should not be replaced by a culture from the same phage group as science and experience show similarities in phage pattern within the same group.

2.1.2 Performance primary cultures

Sugars and organic acids: The below table shows the residual content of sugars and organic acids **(mg/g).** Samples have been inoculated at Cheddar temperature profile for 20 hrs and analyzed on HPLC (High Pressure Liquid Chromatography).

	Citrate	Lactose	Glucose	Galactose	Lactate	Acetic acid
R-603	1.9	42.0	ND	0.3	6.1	0.1
R-604	1.9	42.2	ND	0.3	6.2	0.1
R-607	1.8	41.5	ND	0.4	6.3	0.1
R-608	1.9	42.1	ND	0.3	6.0	0.1
RST-643	1.6	39.5	ND	4.8	6.7	0.1
RST-676	1.6	36.5	ND	4.6	6.8	0.1
RST-630	1.9	34.1	ND	5.0	7.4	0.1
RST-631	1.9	33.6	ND	5.2	7.3	0.1
RSF-621	1.5	34.4	ND	5.2	7.4	0.1
RSF-636	1.7	34.3	ND	4.9	6.1	0.1
RSF-637	1.8	33.8	ND	4.6	6.6	0.1
RSF-638	1.8	33.5	ND	5.4	6.4	0.1

ND = Not detectable

FERMENTATION CONDITIONS : Whole milk 3.5% fat - 72°C (162°F)/15 sec.

TEMPERATURE PROFILE: Cheddar temp. profile: 31°C (88° F) 1 hr 30 min + 38°C (100°F) 4.5 hrs (ramp 30 min) + 16°C (61°F) 15 hrs. Inoculation 0.01% / 500u/5000l.

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Cheddar Cheese

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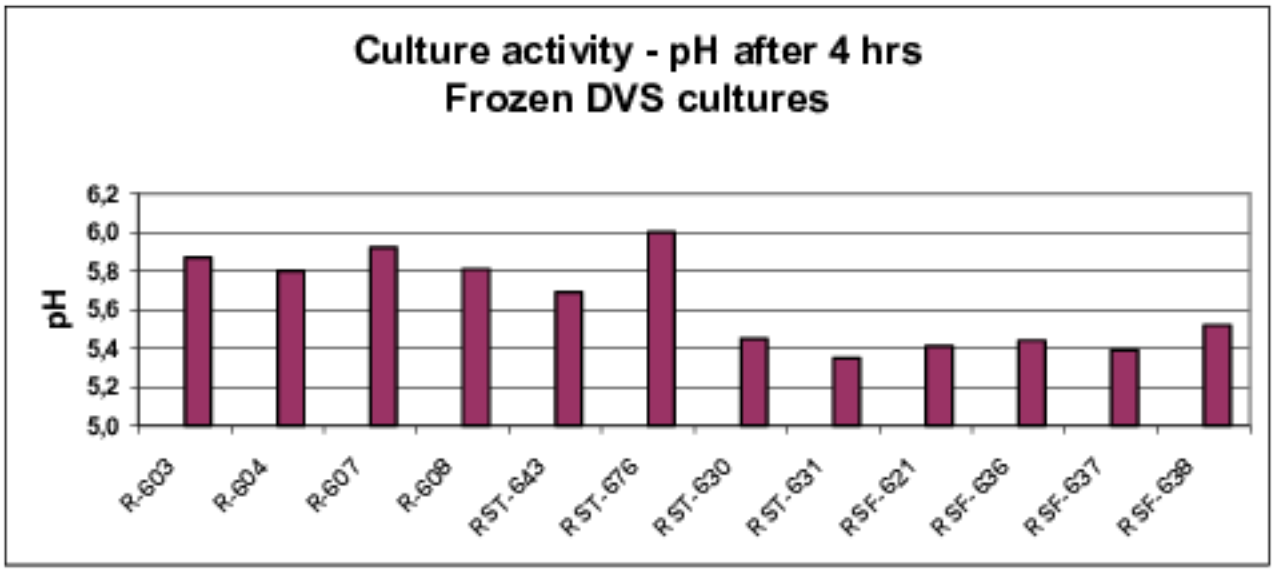
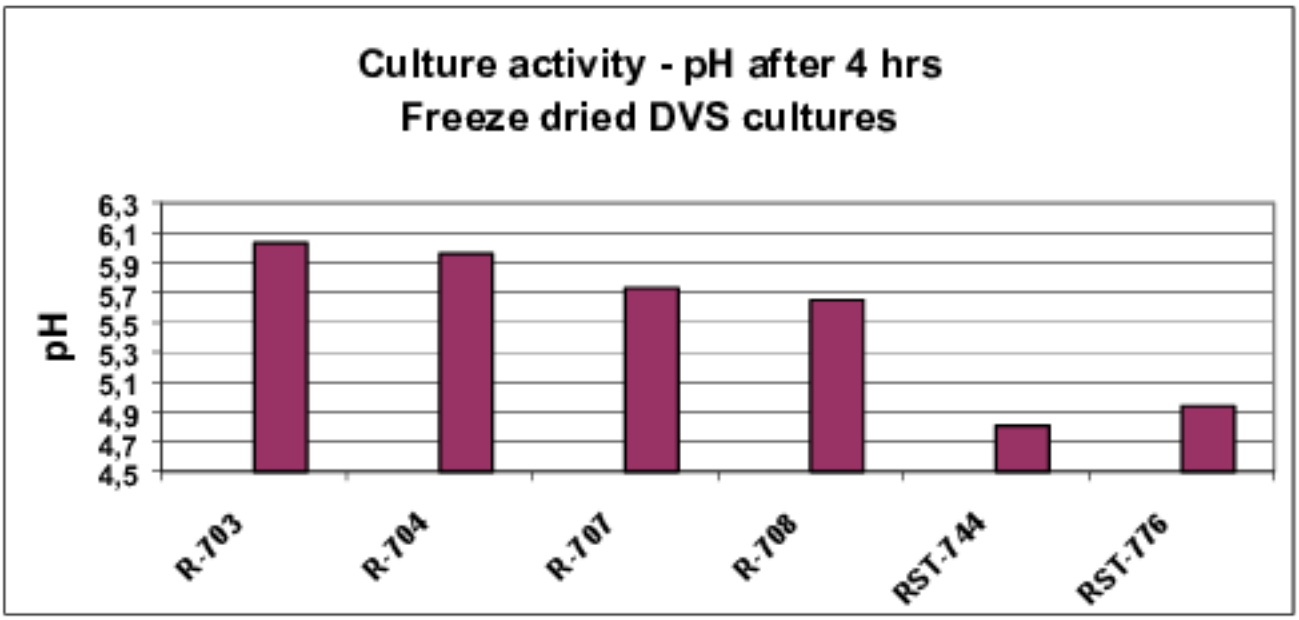
Acidification activity: The figures show the relative activity difference between the Cheddar cheese cultures. The cultures have been inoculated in whole milk at Cheddar temperature profile, and pH has been measured after 4 hrs. *Acidification profiles at specific temperatures are available in our product information sheets.*





FERMENTATION CONDITIONS:
TEMPERATURE PROFILE:

Whole milk 3.5% fat - 72°C (162°F)/15 sec.
Cheddar temp. profile: 31°C (88° F) 1 hr 30 min + 38°C (100°F) 4.5 hrs (ramp 30 min). Inoculation 0.01% / 500u/5000l.

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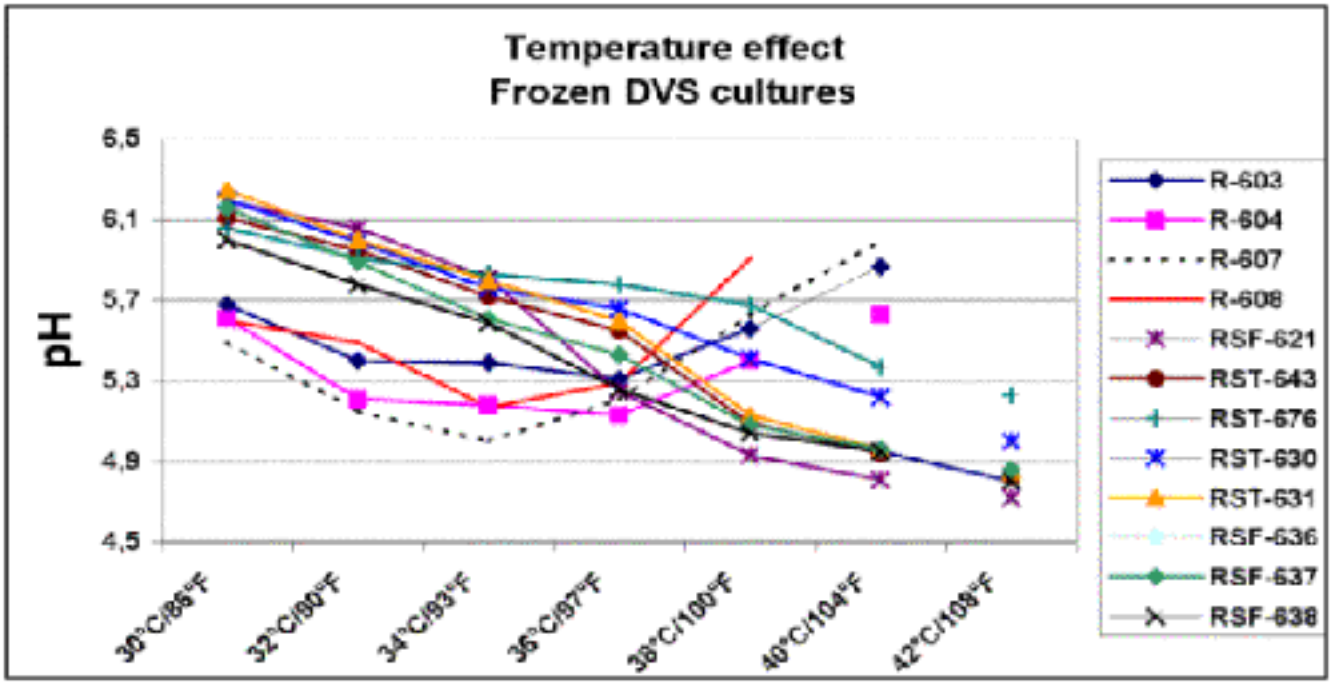
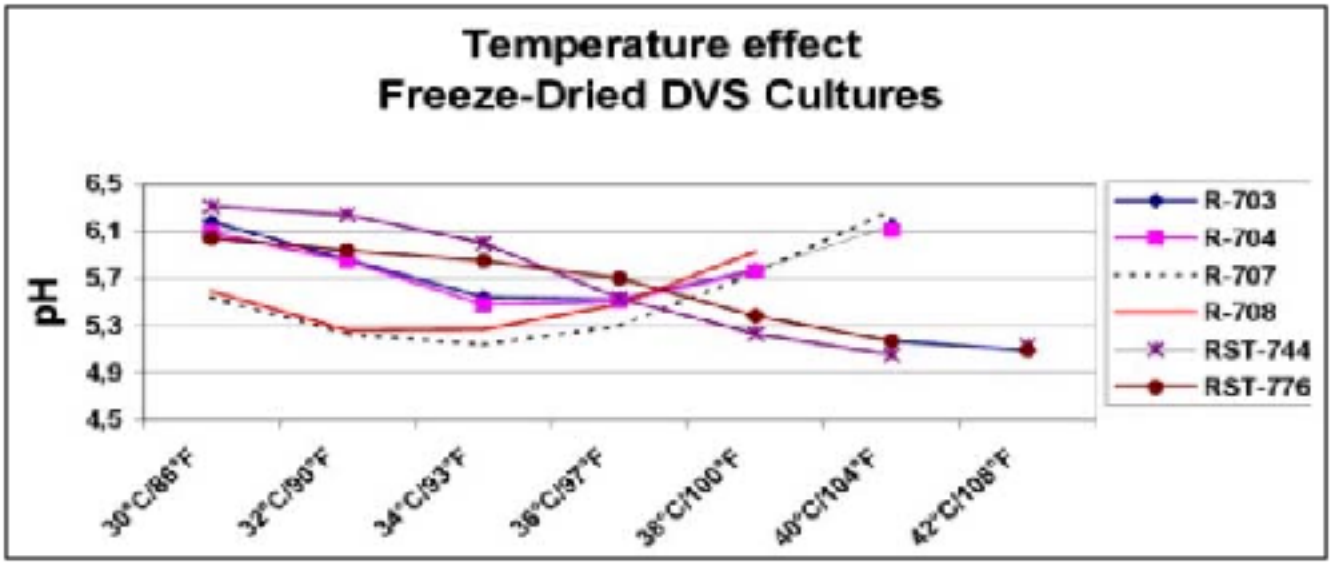
Temperature effect: The figures show the temperature effect on the specific Cheddar cheese cultures. Each culture has been inoculated in lab. milk at different temperatures and the pH has been measured after 6 hrs.





FERMENTATION CONDITIONS: Lab. milk 9.5% DM - 140°C (284°F)/8 sec. - 100°C (212°F)/30 min
Inoculation 0.01% / 500u/5000l

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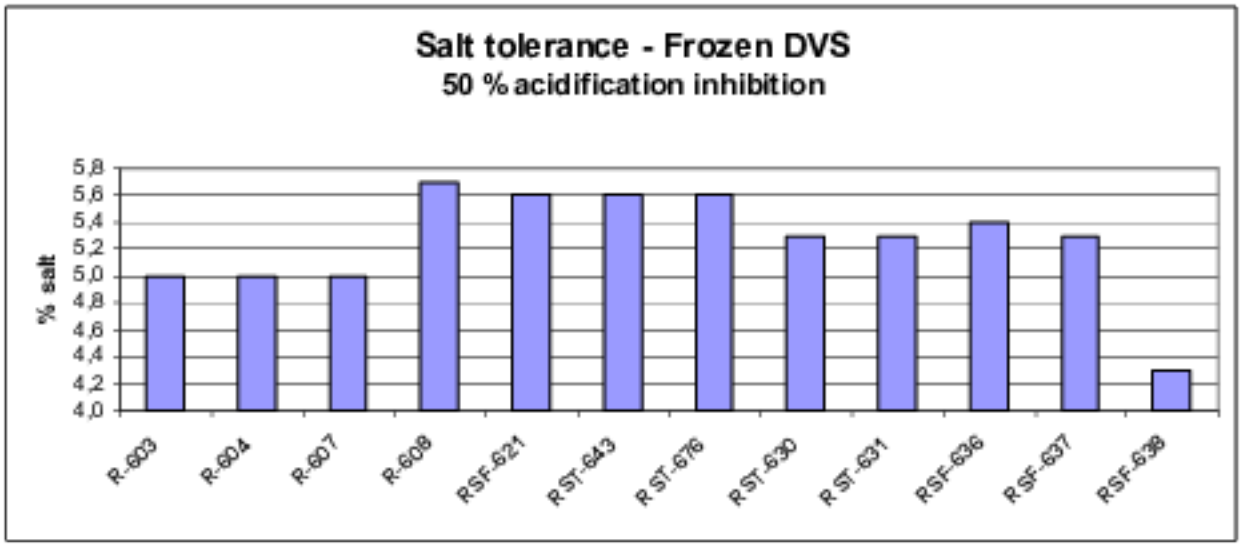
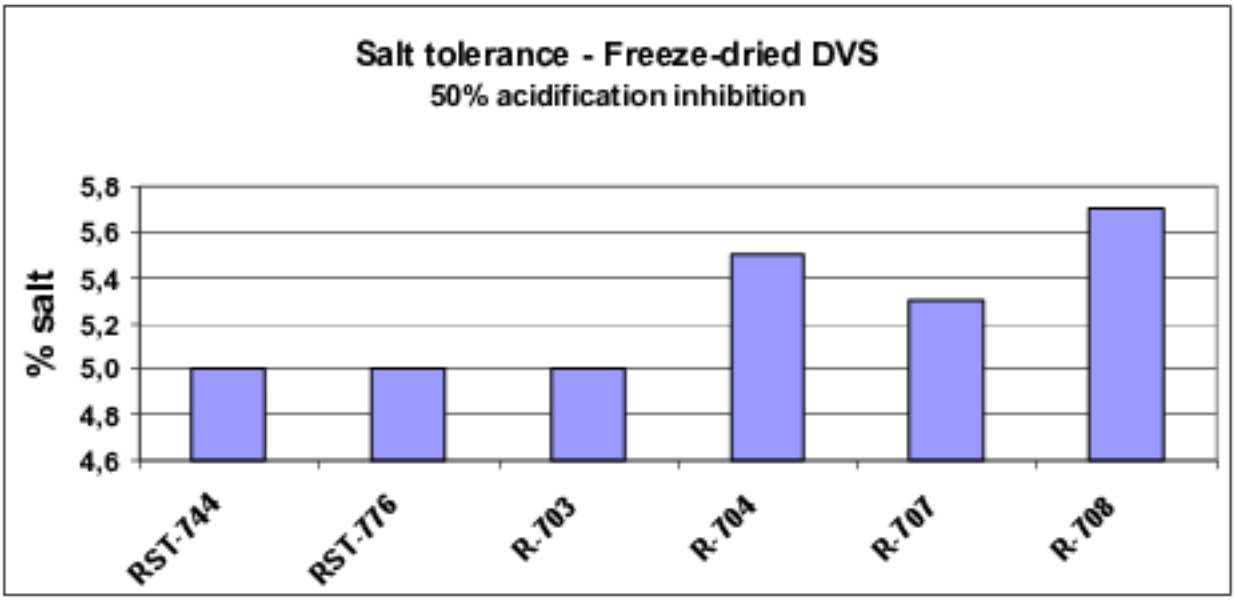
Salt tolerance: The figures below show the specific salt tolerance expressed as a 50% acidification inhibition of each Cheddar cheese culture. Each culture has been inoculated in lab. milk with different salt concentrations, and pH has been measured after 24 hrs. 50% acidification inhibition has been calculated and expressed in the column charts below. The higher the salt concentration needed for 50% acidification inhibition the higher the salt tolerance of the culture.





FERMENTATION CONDITIONS: Lab. milk 9.5% DM - 140°C (284°F)/8 sec. - 100°C (212°F)/30 min
Inoculation 0.01% / 500u/5000l. Temperature 30°C (86°F).

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Ripening cultures

To modify and enhance the flavor in Cheddar cheese the primary starter can be supplemented by the use of attenuated starter cultures such as Flavor Control™ cultures, selected Lactobacilli strains or the use of non-starter adjunct cultures.
The cultures used for modification of ripening during storage can be divided into three main categories

Flavor Control™
Lactobacilli
Coryneforms

Individually, or in combination, these cultures can modify the flavor of cheeses in different directions.

The cultures are added directly to the cheese milk with the primary starter and will, due to the lack of acidification capacity, have no influence on the production of the cheese.

The use of such ripening cultures has been made simpler and more convenient by the introduction of these cultures in direct inoculation form (DVS). This is because the cheesemaker does not have to worry about the preparation of an additional culture as a bulk starter, and the DVS culture can be stored in a freezer and used as required.

Culture	Type
CR-210	Flavor Control™
CR-213	Flavor Control™
CR-312	Flavor Control™
CR-319	Flavor Control™
LH-B02	*Lactobacillus helveticus*
LH-32	*Lactobacillus helveticus*
B.casei	*Coryneforms*

2.2 Direct Vat Set (DVS) cultures

DVS cultures for direct inoculation of the process milk have made a significant impact on modern cheesemaking operations across the world. DVS cultures for cheeses in the Cheddar cheese segment were introduced in the mid seventies and are now able to compete head to head with bulk starter cultures, both in terms of flavor development and speed of activity in the cheese vat. The reasons behind the growth in the use of DVS cultures are based on a number of benefits that these systems offer to the cheese-maker. The key benefits are:

Convenience

- with DVS the cheese-maker does not have to prepare bulk starter in the dairy and can concentrate on making cheese.
- the DVS culture can be used as it is required in the dairy, so there is no bulk starter waste either from overproduction or losses in the system.
- the dairy manager does not have to worry about bulk starter preparation ath the weekend - the DVS culture can be used ´directly from the freezer on Monday mornings.

Safety

- the DVS culture is fully tested for activity and microbiological contaminants before it leaves Chr. Hansen, and certificates of analysis can be provided to support this if required.
- no bulk starter production means less risk of phage contamination leading to slow or lost vats and downgraded cheeses.
- with a range of phage unrelated cultures, our DVS can always provide a back-up culture.

Yield

- standardized DVS culture activity means consistent acid production and performance in the vat. This in turn can result in moisture levels closer to the maximum allowed and increased cheese yield.

Flexibility

- ability to use DVS cultures in special combinations producing different cheese types and flavors without the need for additional bulk starter facilities.

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2.3 Using DVS cultures

DVS cultures should be stored as closely as possible to the cheese vat and taken from the freezer immediately prior to use. Alternatively, they can be transferred to the vat platform and kept in a cool box for short periods (10-15 mins.) prior to use. Inoculate directly into the cheese vat as soon as a thin layer of milk has covered the bottom of the vat. Good agitation of the vat milk improves the dispersion of the culture.

The use of DVS cultures in place of bulk starter requires some very minor changes to the manufacturing process. These changes are required because when bulk starter, with a pH of around 4.6, is added to the cheese vat there is an immediate, but small, drop in the milk's pH. This drop does not occur when DVS cultures are used because the inoculation with DVS is about 100 times lower than inoculation with bulk starter.

We usually recommend the use of an increased pre-ripening period and the choice of the right DVS culture for the cheese type to be produced. This can be achieved without the overall process time being increased; but since each dairy has its own particular needs we advise close collaboration with our Applied Technology Laboratory technicians to ensure that the introduction of DVS cultures runs smoothly.

2.4 Coagulants

Chr. Hansen is able to supply a full range of coagulants. It is within this particular segment that we have our longest track record, having supplied rennet for over 125 years. We have adapted our range to fit your needs, linking tradition with research and innovation.

Chr. Hansen's coagulant range:
NATUREN®: Animal rennet (calf and/or bovine)
CHY-MAX®: Chymosin produced by fermentation

MICROLANT™: Microbial coagulants

These three groups have varying characteristics for proteolytic activity, heat lability and sensitivity to changes in pH, temperature and $CaCl_2$. Traditionally, calf rennet has been regarded as the ideal cheese coagulant because of its highly specific milk clotting activity. CHY-MAX® shares this characteristic and is rapidly winning ground all over the world to be the preferred choice of cheesemakers.

The last two groups, CHY-MAX® and Microlant™, are approved for use in kosher, halal and vegetarian products. CHY-MAX® is also available in a kosher quality approved for Passover. This opens up completely new opportunities for you.

Furthermore, we can demonstrate the effect each of these coagulants has on your yield. This may not be more than a fraction of a percentage point - but sufficient to make a measurable impact on the bottom-line result for your business. You should, for example, be able to achieve an improvement of around 0.5% in yield by switching from a microbial coagulant to our very specific CHY-MAX or to a High Chymosin Naturen type.

Being a full-range supplier we can give you objective advice designed to achieve the optimal solution for your particular process. But optimization of production is not simply a question of enhancing the yield from a specific quantity of milk. The characteristics of the end product are at least as significant. For instance, side activity is an important issue, particularly when your cheese or whey is used as an ingredient in other products.

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Whey is often a significant additional source of profit in cheesemaking. Highly nutritious, it is a valuable ingredient in a wide range of foods. However, for whey of the right quality to be produced, it is important to select exactly the right coagulant for your cheesemaking.
Consistent clotting activity, specific proteolytic activity, side activity, yield, maturation, flavor and texture, whey, certification - all in all there are over 30 interactive parameters to be taken into consideration when choosing the right coagulant. It is a complicated jigsaw but we offer you our expertise to help you solve it.

From the sourcing of raw materials to the on-time delivery at your doorstep, our commitment is driven by your requirements.

2.5 Other ingredients

Natural Colors

Cheese may be colored using a large variety of natural colors supplied from Chr. Hansen. They are all extracted from natural sources. The colors most often used are described below.

Coloring the whole cheese

Cheddar can be colored from warm yellow to deep orange using annatto or carotenes.

Color Type	Color product	Color Shade	Origin
Chlorophyll	C-130-WS-Blego	Green	Green dried plants
Turmeric	T-TP8-WS	Fresh yellow	Turmeric root
Beta Carotene	BC-140-WSS	Yellow	Artificial or nature identical
Natural Carotene	Natural carotene WS2	Fresh Yellow	Palm fruit oil
Annatto	A-320-WS	Warm Yellow	Annatto seeds
Paprika	P-40,000 G-WS	Orange	Paprika fruits
Carmine	CC-500-WS	Red	Cochineal
Caramel	CA-19,000C-WS	Brown	Heat treated sugar

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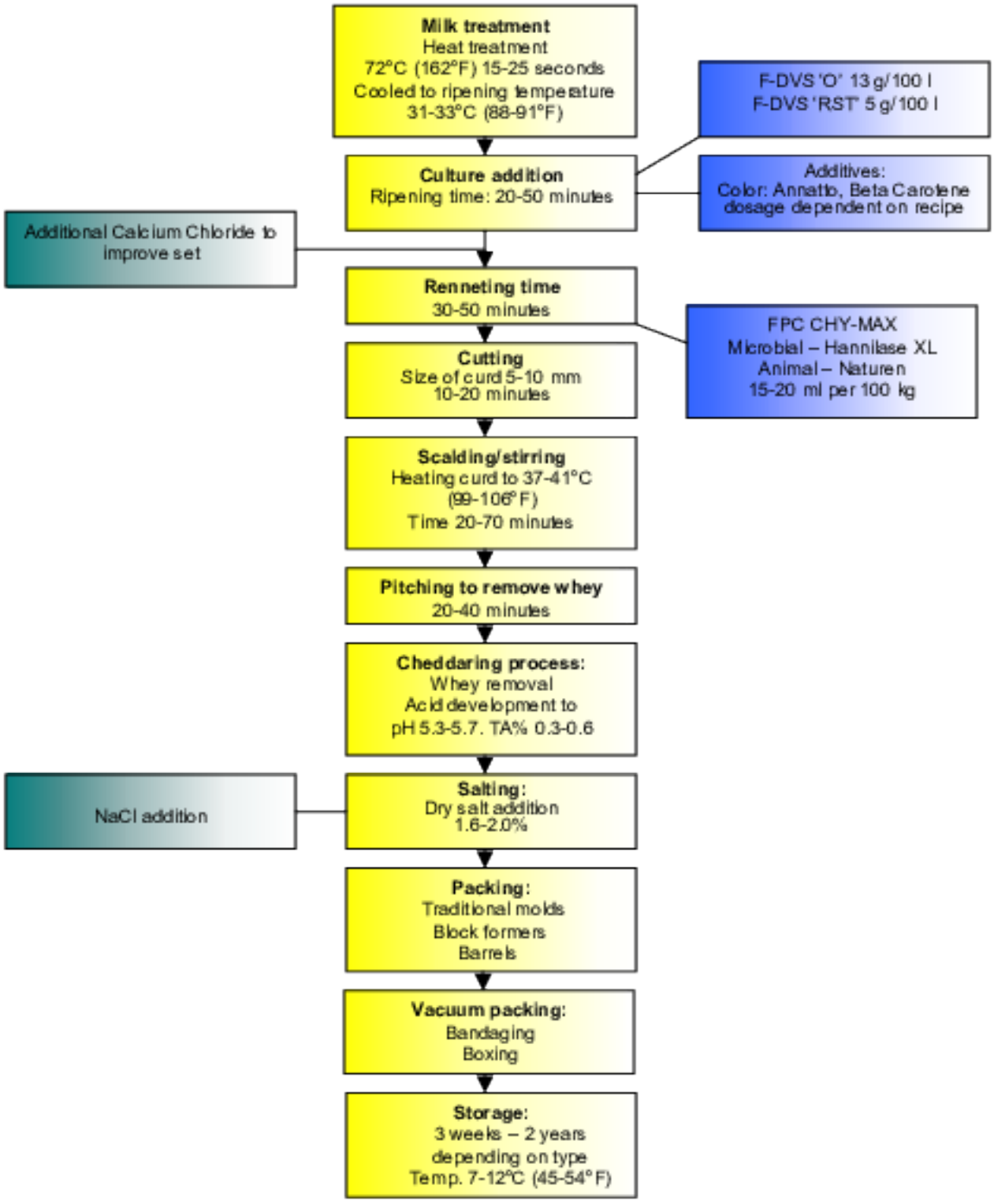
4. Production procedure

4.1 Typical Cheddar manufacturing process



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4.2 Critical manufacturing points

During the production of Cheddar cheese parameters such as acidification rate and flavor development are critical in obtaining the right quality:

Acidification	Flavor (and Aroma)
* through controlled development of lactic acid the starter culture ensures final cheese moisture, texture, consistency, and pH targets are met * the pH of the cheese after salting should be pH 5.3-5.7 (TA 0.3 - 0.6%). This target pH value will differ according to the type of cheese being produced, e.g. full fat, low fat etc * For some cheese types (e.g. curd for processing) 4 day pH is important. pH should be between 5.1 - 5.3.	* the cheese produced should have the desired flavor and aroma typical for the cheese type and its intended market * with controlled proteolysis and lipolysis, from among other things the starter culture, no off or bitter flavors should occur that could result in down-grading or the cheese having to be sold before its targeted maturing date.

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4.3 Cheddar manufacturing technology

Heat treatment

From a food safety point of view, the pasteurization step is important to eliminate any pathogenic organisms that may be in the raw milk. It is important not to over heat-treat the milk as this will adversely affect the coagulation stage by denaturing too much whey protein and result in a poor set. Milk is cooled to inoculation temperature, which for most Cheddar type cheeses is between 30° and 33°C (86° and 91°F).

Culture addition

The culture is added to the milk as it enters the vat during filling. With DVS culture, the milk pH is not changed at this stage (due to the bulk starter's acidity, the pH of the vat milk will normally drop by 0.2 pH units). DVS cultures hydrate quickly and begin acid development that continues throughout the make.

Ripening time is usually between 20 and 50 minutes. A shorter ripening time helps minimize phage attack; this must be balanced against the total make time required.

If the recipe requires addition of color or calcium chloride they are added at this stage, prior to setting.

Coagulant addition

Coagulant is added to set the milk, so that it can be cut to produce curd particles. The temperature, pH, amount and type of coagulant determine the setting time. A higher temperature, lower pH and increased usage rate will result in a faster set. The type of coagulant used will have an effect on the yield and flavor profile of the cheese further down the process.

Cut

It is important to cut at the correct gel strength to optimize cheese yield. If the set is too weak, this can result in broken curd and excessive loss of fat and protein into the whey resulting in lost yield. If the set is too firm, this can result in tearing of the curd, again resulting in loss of fat and protein to the whey.

The size of cut is a key control on the final cheese moisture. For a high-moisture cheese the cut size is as large as possible and for a lower moisture cheese, the cut size is much smaller.

Prior to the start of scalding, the curd is normally stirred for a short time to prevent the curd particles from case hardening; normally known as the 'healing' time.

Scald temperature

Heating causes the curd particles to contract, expelling moisture. The final scald temperature reached is another way to control the moisture composition of the final cheese. When using the mesophilic, thermophilic blends the temperature at scald will have a significant effect on the rate of acidification after the curd has been pitched.

Usually there is stirring period after the target scald temperature has been reached, this time will also have an effect on the final composition of the cheese.

Mill acidity

Having pitched the curd and whey out of the vat, there are numerous mechanical systems for removing the whey, to allow the curd to 'cheddar'. As the acidity develops, the curd expels whey and mats together. Here the rate of acidification can affect the final moisture and the texture of the resulting cheese.

Having achieved the desired pH or acidity, the curd is passed through a mill which cuts the matted curd into small pieces, or chips.

Salt addition

Salt is added to the milled curd and serves a number of functions. Salt is important for the flavor and textural development of the cheese, it tends to retard acidification of the curd and prevents undesirable microorganisms from contaminating the curd. The amount of salt added is important, over salting can result in very slow maturation of the curd, conversely under salting can give rise to contamination and undesirable flavor characteristics.

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Types of manufacturing equipment

There are a number of manual and automated systems for manufacturing Cheddar. Here is a brief summary of the main types in use:

Traditional

Here curd is pitched onto tables or coolers where the curd is either block and turned manually in the traditional manner or where overhead stirrers and cutters handle the curd.

Tower

Here the curd is pitched onto belt one and this carries the curd up to an auger. Most of the whey is drained off before the curd is blown into a tower where the cheddaring process takes place. From the tower the curd is guillotined into blocks that fall into the mill. From here the curd goes onto a second belt where it is salted. The curd is then moved from belt two to a curd packing system.

Belts

Curd is pitched onto a series of belts, up to four sometimes, where the whey is removed and cheddaring occurs as the mat of curd passes from one belt to the next. Having been milled and salted on the final belt the curd is blown across to the curd packing system.

Packing of curd

Traditional molds and gang-presses:

These are a manual system used in smaller factories. Curd is packed into molds and these are then pressed in horizontal or vertical presses. Pressing usually overnight; the molds are then emptied and the blocks are vacuum packed.

Block Formers

The curd is blown into a tower, which forms the curd into a rectangular column. With the aid of a vacuum the curd is pressed together, a guillotine cuts off blocks of the formed curd at the base and these are vacuum packed.

Storage

The packed curd is stored at between 7° and 10°C (45° and 50°F). Depending on the cheese type, the curd is left to mature from 2 weeks up to 2 years.

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5. Cause and prevention of faults in cheese in the Cheddar segment

Problem	Cause	Prevention
High moisture in cheese or high fat content could result in: - flavor too acid - body weak - open texture	High fat content Slow acid development Insufficient scald Too rapid scald Poor whey drainage	Standardize fat Increase ripening time, increase culture inoculation, increase scald temp, scald slower
Low moisture in cheese could result in: - dry cheese - body firm and hard - texture curdy, crumbly	Too much coagulant Cut too small Scald too high Over salted Acid development too fast	Reduce rennet, or set time Larger cut Lower scald, mill at higher pH Reduce salt
Minimum pH in cheese too low (over acid): - too acid, bitter - body too dry (low moisture) - body too pasty (high moisture) and could be mottled if colored	Inoculation too high Pre-ripening time too long Milling acid too high	Reduce culture inoculation Shorter pre ripening Scald higher Increase salt
pH in cheese too high (low TA): - low flavor intensity, off flavors can develop, body slow to break down, mottling	Culture failure Phage Antibiotics Rotate cultures	Improve hygiene, CIP's Reject suspect milk Increase culture, ripening time

Textural defects - curdy (chippy) body	Low fat Lack of acid Scald too high	Higher TA at milling (lower pH) Lowered scald
Crumbly body - fractures, crumbles when sliced	Excessive proteolysis in older cheese	Culture selection, increase moisture
Pasty body - very soft body, sticky	Excessive moisture	Higher TA at milling (low pH) Higher scald
Open texture - gas formation	Contamination with heterofermentative NSLABs or yeasts	Improve hygiene Increase acid production
Color defects - Bleaching	Acid too high in make	Reduce acidity
Mottling	Uneven acid formation Uneven salting	Culture selection Improve salt/curd mixing
Bitter cheese	Unbalanced proteolysis Contamination of milk – or curd during process Incorrect choice of culture Incorrect ripening time and temperature	Good hygiene Correct culture selection Use of flavor attenuating cultures

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Appendix 1
Typical cheese types in the Cheddar segment

Cheese Type	Description	Maturation Age	Scald Temp / °C (°F)	Mill TA	Rennet to Mill Time
Mild Cheddar	Soft texture, clean flavor	3 - 8 weeks	37–39 (99-102)	0.4 - 0.5%	3hrs 45 - 4hrs
Mature Cheddar	Firmer texture, full flavor, rounded, some acidic bite	6 - 24 months	38.5-41 (101-106)	0.45 - 0.6%	4hrs - 4 hrs 30 min
Cheshire	Crumbly, texture, moist, sharp acid flavor, diacetyl flavors	2 - 6 weeks	32-33 (90-92)	0.6 - 0.7%	2hrs 30min - 2hrs 45min
Red Leicester	Open texture, flinty, full rugged flavor, dark red color	8 - 14 weeks	37-39 (99-102)	0.4 - 0.5%	3hrs 40 - 4hrs
Double Gloucester	Smooth, soft texture, mild rounded flavor pale orange color	8 - 14 weeks	37-39 (99-102)	0.4 - 0.5%	3hrs 40 - 4hrs
Reduced Fat Cheddar	Firm texture, rounded flavor some acid	3 - 12 months	35-36 (95-97)	0.3 - 0.4%	3hrs - 3hr 20
Colby	Smooth soft texture, mild flavor, bright orange to red	2 – 5 weeks	36–39 (97-102)	0.2 – 0.3%	2hrs 30 – 3hrs
Monterey Jack	Smooth soft texture, mild flavor	2 – 5 weeks	36–39 (97-102)	0.2 – 0.3%	2hrs 30 – 3hrs
US barrel Cheddar for processing	Firm texture	1 week	37–40 (99-104)	0.4 – 0.7%	2.5hrs – 3 hrs

The information contained herein is to our knowledge true and correct and presented in good faith. However, no warranty, guarantee, or freedom from patent infringement is implied or inferred. This information is offered solely for your consideration and verification.

EN-Cheddar-0801

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