Effects of DATEM on Dough Rheological Characteristics and Qualities of CSB and Bread

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ABSTRACT

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Diacetyl tartaric acid ester of monoglycerides (DATEM) is a kind of anionic emulsifier. To date, the positive effect of DATEM on the volume of bread has been reported, but the effects on Chinese steamed bread (CSB) quality and other parameters for bread quality are still unclear. The effects of DATEM on the characteristics of dough and the qualities of CSB and bread were investigated. The results showed that, the effects of DATEM on the rheological properties of dough were complex. Water absorption ratio of CSB dough decreased slightly, while that of bread dough increased slightly. But gas retention and structure improved and gluten strength increased for both CSB and bread doughs after DATEM was added. The studies also showed that structure, elasticity, tenacity, and whiteness of CSB were improved, but specific volume was almost unchanged. The structure, color, and smoothness were significantly improved for bread, and specific volume increased compared with the control. The optimal quantities of DATEM for CSB and bread were both ≈0.10% (on flour mass basis).

Diacetyl tartaric acid ester of monoglycerides (DATEM) is an anionic oil-in-water emulsifier (Inoue et al 1995; Ribotta et al 2004); the molecular formula is CH_2O = $OCHOCOCH_3CHOCO$ CH_3COOH–$CHOH$–$CH_2OCO(CH_2)_{16}CH_3$. The hydrophile-lipophile balance (HLB) value of DATEM is ≈8–10. Acceptable daily intake is ≈0–50 mg/kg. Lethal dose 50% (LD_{50}) for DATEM is 10 g/kg of body weight, respectively. DATEM is often used to increase the volume of bread and has been reported as an effective bread emulsifier in many countries (Yang 1994; Kokelaar et al 1995; Jin et al 1996; Stampfli et al 1996).

DATEM can enhance the resistance of dough to collapse and improve gas retention of dough, so it is also a dough strengthener (Inoue et al 1995; Ribotta et al 2004). Commercial DATEM is a mixture of several components including DATEM, monoacetyl tartaric acid ester of monoglycerides, acetic acid, esterification products of tartaric acid, and acetic acid. The influence of DATEM on dough quality varies with the components of DATEM (Kohler 2001a). If DATEM contains hydrophilic radicals such as diacetyl radical and hydroxyl, they will interact with large amounts of water, which is favorable for the water retention of dough (Frank and Smith 1998). As a result, the aging speed of bread is reduced. DATEM components with two carboxyl groups had the lowest baking activity but they were most active in dough and gluten rheology (Kohler 2001b). In addition, DATEM can strongly interact with proteins, especially glutenin, thus gas retention of dough is improved and the formation of a gluten-starch-fat network structure is accelerated (Zhang 1993b; Stampfli et al 1996).

Although it is widely used in processing CSB and bread, there are few reports on the effects of DATEM on qualities of CSB and bread except for the positive effect of DATEM on bread volume. This investigation compared the effects of DATEM on dough rheological properties and on CSB and bread qualities.

MATERIALS AND METHODS

Materials

Shenxiang is a special first-grade flour (moisture content 13.36%; wet gluten content 28%; gluten index 64.5%; falling number 481 sec) obtained from the Zhengzhou Haijia flour mill in China. The Jinyuan bread flour (moisture content 14.1%; wet gluten content 32%; gluten index 92.3%; falling number 446 sec) was obtained from the Zhengzhou Jinyuan flour mill in China. DATEM was procured from Henan Zhengtong Chemicals in China. Instant active dry yeast used in the preparation of CSB and bread was provided by Meishan Mauri Yeast Company in China.

Flour Quality Tests

Moisture content was determined by Approved Method 44-16 (AACC International 2000). Wet gluten content and gluten index were determined according to Approved Method 38-12. Falling number was obtained according to Approved Method 56-81B.

CSB Preparation (SB/T 10139-1993)

All ingredients for CSB were accurately weighed: 100 g of flour, 1 g of instant active dry yeast, 48 g of water, and varying quantities of DATEM. The ingredients were put into an aluminum basin in order and mixed by hand until optimum dough consistency was obtained. After resting for 15 min at room temperature, the dough was molded into a hemisphere-like shape (6.0 cm height) on a smooth surface. After proofing for ≈30 min in an incubator at 30°C and 70% relative humidity (RH), the shaped dough was put into a steamer with boiling water and steamed for 20 min. Procedures followed PRC, Bureau of Technical Supervision, National Standard SB/T 10139-1993.

Quality Evaluation of CSB (GB/T 17320-1998)

After cooling to room temperature, CSB weight was measured with a DS-671 electronic scale. Volume of CSB was determined by rapeseed displacement. The specific volume was calculated as specific volume = volume/weight. Height (H) and diameter (D) of CSB was measured with a ruler and the H/D ratio was calculated as H/D ratio = height/diameter. Scores for CSB quality parameters were specific volume (0–15), H/D (0–5), skin color (0–10), skin structure (0–10), appearance shape (0–10), inner structure (0–15), elasticity (0–10), tenacity (0–10), viscosity (0–10), savor (0–5), total score was 100 points. The panel included five professional teachers and five students who knew CSB well. The ages of the 10 participants (two men and eight women) ranged from 23 to 40. Nine samples, including a standard sample, were evaluated each day. Assessments were made in triplicate. Procedures followed PRC, Bureau of Technical Supervision, National Standard GB/T 17320-1998.

Preparation of Bread Sample (GB/T 14611–1993)

Dough made from flour with variable amounts of DATEM (500 g), instant active dry yeast (8 g), salt (5 g), sugar (100 g), shortening (40 g), and water (270 g) was made in a flour mixing machine.

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DATEM was sifted with the flour to ensure a uniform distribution throughout the dough. Salt and sugar were dissolved in water first. After mixing, the dough was immediately taken out and rested for 10 min at room temperature, then the dough was divided and shaped into several round pieces and let stand for another 10 min. After standing, the dough pieces were shaped to loaves and then proofed for ≈90 min in an incubator at 39°C and 80% RH. The shaped and proofed dough pieces were baked in an oven at 150°C (above) and 210°C (below) for 25 min. Procedures followed PRC, Ministry of Commerce, Bureau of Technical Supervision, National Business Standard GB/T 14611-1993.

Quality Evaluation of Bread (GB/T 14611–1993)

Specific volume of bread was determined as for CSB. After cooling to room temperature, breads were randomized and evaluated by five highly trained assessors for specific volume (0–35), skin color (0–5), skin texture (0–5), crumb color (0–5), smoothness (0–10), crumb structure (0–25), elasticity (0–10), and mouthfeel (0–5). Procedures were PRC, Bureau of Technical Supervision, National Standard GB/T 14611-1993. Duplicate assessments were made.

Rheological Properties

Farinograph and extensigraph tests were performed according to Approved Methods 54-21 and 54-10, respectively (AACC International 2000). Detection of dough rheological properties was made in duplicate.

Experimental Design

To investigate the effects of DATEM on the qualities of CSB and bread, seven levels of DATEM (0.03, 0.05, 0.08, 0.10, 0.20, 0.50, and 1.00%) were used to make CSB and five levels of DATEM (0.05, 0.07, 0.10, 0.40, and 0.60%) were used to make bread. In addition, DATEM was used at three (0.03, 0.08, and 0.10%) and four levels (0.03, 0.05, 0.08, and 0.10%) for investigating the effects of DATEM on the rheological properties of CSB and bread dough.

Statistical Analysis

Each treatment was prepared randomly on different days in at least two replicates. Statistical analysis of the data was performed using SAS statistical software. One-way ANOVA was used to analyze the data to ascertain whether the quantities of DATEM significantly affected qualities of CSB and bread or the dough rheological properties. Significance level was $\alpha = 0.05$.

RESULTS AND DISCUSSION

Effects of DATEM on CSB Quality

The quality of CSB varies with the DATEM addition as shown in Table I. It indicated that, except for specific volume, H/D, appearance shape, elasticity, and savor, DATEM significantly affected almost all of the CSB characteristics. Tenacity of CSB increased but viscosity decreased (therefore the scores increased) with the

TABLE I
Effects of DATEM Addition on CSB Quality[a]

DATEM Conc. (%)	Specific Vol. (15)[b]	H/D (5)[c]	Skin Color (10)[d]	Skin Structure (10)[e]	Appearance Shape (10)[f]	Inner Structure (15)[g]	Elasticity (10)[h]	Tenacity (10)[i]	Viscosity (10)[j]	Savor (5)[k]	Total Score (100)
0.00	10.0a	4.8b	8.0e	8.0d	8.0b	11.0g	9.0a	7.0e	7.0e	4.5a	77.3f
	(0.22)	(0.16)	(0.25)	(0.17)	(0.25)	(0.81)	(0.17)	(0.45)	(0.61)	(0.24)	(3.12)
0.03	9.0b	4.8b	8.3d	8.2c	8.0b	11.5f	9.0a	7.5d	8.0d	4.5a	78.8e
	(0.33)	(0.14)	(0.17)	(0.17)	(0.33)	(0.48)	(0.35)	(0.21)	(0.25)	(0.20)	(2.54)
0.05	10.0a	5.0a	9.0c	8.5b	8.5a	12.0e	9.0a	8.0c	8.2c	4.5a	82.7d
	(0.31)	(0.00)	(0.21)	(0.26)	(0.17)	(0.65)	(0.25)	(0.05)	(0.21)	(0.17)	(2.20)
0.08	9.0b	5.0a	9.5b	8.5b	8.5a	12.5d	9.0a	8.5b	8.5b	4.5a	83.5c
	(0.33)	(0.00)	(0.17)	(0.18)	(0.14)	(0.41)	(0.52)	(0.32)	(0.57)	(0.31)	(2.70)
0.10	9.0b	5.0a	10.0a	9.0a	8.5a	14.0a	9.0a	9.0a	8.7a	4.3b	86.5a
	(0.37)	(0.00)	(0.00)	(0.31)	(0.17)	(0.50)	(0.43)	(0.10)	(0.26)	(0.26)	(1.90)
0.20	9.0b	5.0a	9.6b	8.5b	8.5a	13.7b	9.0a	9.0a	8.6ab	4.5a	85.4b
	(0.16)	(0.00)	(0.21)	(0.21)	(0.16)	(0.54)	(0.19)	(0.27)	(0.16)	(0.15)	(2.05)
0.50	10.0a	5.0a	9.6b	8.2c	8.5a	12.8c	9.0a	9.0a	8.5b	4.5a	85.1b
	(0.20)	(0.00)	(0.16)	(0.22)	(0.22)	(0.31)	(0.62)	(0.38)	(0.17)	(0.10)	(2.36)
1.00	10.0a	5.0a	9.6b	8.2c	8.5a	12.8c	9.0a	9.0a	8.5b	4.5a	85.1b
	(0.10)	(0.00)	(0.22)	(0.18)	(0.14)	(0.31)	(0.49)	(0.32)	(0.26)	(0.34)	(2.21)

[a] Values in parentheses are standard deviation of quality evaluation values for Chinese steamed bread (CSB) at each DATEM level. Values within a column with different letters are significantly different ($P < 0.05$). Standard error of mean at 16 degrees of freedom.
[b] At 2.8 mL/g, 15 points; specific volume reduces by 0.1 mL/g from 2.8 mL/g, deduct 1 point.
[c] At 0.70, 5 points; H/D reduces by 0.05 from 0.70, deduct 1 point.
[d] White or milk-white, 8–10 points; yellow, 6–8 points; gray or dark, 2–6 points.
[e] Smooth, 8–10 points; crinkled, collapsed, with air bubble or spots, 3–8 points.
[f] Symmetrical, straight, spherical, 7–10 points; flat or dissymmetrical, 4–7 points.
[g] With minute and uniform air holes, 12–15 points; with uniform but excessive dense air holes, 8–12 points; with big air holes and rough structure, 5–11 points; with separation between crumb and crust, 2–8 points.
[h] Rebounds quickly, compressible, 7–10 points; difficult to press down and hard, 2–6 points.
[i] Chewy, 7–10 points; poor chewing quality, 4–7 points.
[j] Tasty and does not stick to the teeth, 8–10 points; a little sticky, 3–7 points.
[k] Good savor, with favorable wheat aroma, 4–5 points; faint savor, 3–4 points; with abnormal savor, 1–3 points.

TABLE II
Effects of DATEM Addition on Farinograph Properties of CSB Dough[a]

DATEM Conc. (%)	Water Absorption Ratio (%)	Development Time (min)	Stability Time (min)	Softening Degree (BU)	Evaluation Value
0.00	59.8a	2.0d	4.1b	109a	48d
0.03	59.1b	3.3c	4.0c	106ab	52c
0.08	58.6c	4.0b	4.1b	94c	60b
0.10	58.9bc	4.5a	5.2a	99bc	65a

[a] Values within a column with different letters are significantly different ($P < 0.05$). Standard error of mean at 4 degrees of freedom.

addition. The most important aspects (skin color, skin structure, inner structure, and total score) cleary varied with the variation of DATEM addition. These results are probably due to the reactions of DATEM and fat, protein, and carbohydrate molecules in dough which stabilize and strengthen the gluten structure (Tang 2001).

With the increase of DATEM addition, skin color, skin structure, inner structure, and total score of CSB significantly improved initially, but if the quantity was >0.10%, these scores decreased slightly. Therefore, the optimal quantity of DATEM added in CSB was 0.10%. This is probably because, with the increase of DATEM, the emulsification effect is enhanced gradually, but when the addition is >0.10%, the emulsification effect of DATEM cannot be enhanced any further (Zhang 1993a). Compared with the control, the CSB with 0.10% DATEM had smaller specific volume but the inner structure significantly improved with even air holes and scores of color, tenacity, and viscosity significantly increased.

Effects of DATEM on CSB Dough Properties

The sensory analysis results showed that the optimal quantity of DATEM was at the 0.10% level. To verify the results above, three dough samples with different levels of DATEM (0.03, 0.08, and 0.10%) were selected and their rheological properties were determined. The effects of DATEM on farinograph and extensigraph properties of CSB dough are shown in Tables II and III

Table II shows that the effects of DATEM on farinograph properties are complex. As the DATEM level increased, development time was prolonged. Water absorption ratio decreased slightly. Stability time was almost unchanged when DATEM levels were <0.08%. With increased DATEM, softening degree decreased and evaluation value increased. Table III shows that the effects of DATEM on extensigraph properties are equally complex.

Compared with the control, extensiveness and powdered strength decreased, however extended resistance decreased at first and then increased, while extended ratio changed little.

Tables II and III lead us to conclude that the gas retention and structure of CSB dough improved, while gluten strength increased after DATEM was added. The effects of DATEM on the rheological properties of dough were complex, so attention should be paid to the quantity of DATEM used in making CSB.

As a surfactant, DATEM can attach to the surface of starch particles and form an indissolvable film, so the water absorption ratio of dough will decrease. However, the effect of DATEM on water absorption ratio was quite weak (Toufeili et al 1995), which is in accordance with the trial results above. DATEM can react with fat, protein, and carbohydrate molecules in dough, thus stablizing and strengthening the gluten structure. DATEM can also react with amino acids and form hydrogen bonds, which leads to the strengthening of the gluten network structure and, consequently, improves gas retention of gluten (Tang 2001). Owing to the existence of diacetyl residues, anion residues in DATEM can effectively neutralize the cation residues in gluten and thereby reduce the charge quantity of gluten, which favors gluten conglomeration and, improves the strength and gas retention of gluten (Kohler 2001c). The results also showed that DATEM addition is especially suitable for the European and Asian wheat flours with low protein content and weak gluten strength (Jin et al 1996).

Effects of DATEM on Bread Quality

The effects of DATEM on bread quality are shown in Table IV. DATEM significantly affected bread quality. Adding DATEM improved the overall quality of bread compared with the control. Specific volume and crumb structure were significantly affected

TABLE III
Effects of DATEM Addition on Extensigraph Properties of CSB Dough[a]

DATEM Conc. (%)	Extensibility (mm)		Extended Resistance (BU)		Maximal Extended Resistance (BU)		Extended Ratio		Maximal Extended Ratio		Powdered Strength (cm^2)	
Standard[b]	45*	135*	45*	135*	45*	135*	45*	135*	45*	135*	45*	135*
0.00	166a	149a	100a	174a	140a	218a	0.6b	1.2a	0.8b	1.5a	32a	44a
0.03	144b	135b	96a	166b	130b	201b	0.7a	1.2a	0.9a	1.5a	25c	37b
0.08	131c	135b	81b	135d	105c	166c	0.6b	1.0c	0.8b	1.2c	18d	30d
0.10	147b	139b	100a	150c	139a	196b	0.7a	1.1b	0.9a	1.4b	28b	36c

[a] Values within a column with different letters are significantly different ($P < 0.05$); standard error of mean at 4 degrees of freedom.
[b] * Indicates standard for proof time (min) of dough with DATEM.

TABLE IV
Effects of DATEM Addition on Bread Quality[a]

DATEM Conc. (%)	Specific Volume (35)[b]	Skin Color (5)[c]	Skin Texture (5)[d]	Crumb Color (5)[e]	Crumb Smoothness (10)[f]	Crumb Structure (25)[g]	Elasticity (10)[h]	Mouthfeel (5)[i]	Total Score (100)
0.00	28.5c (0.64)	4.5b (0.22)	4.0c (0.18)	4.0c (0.32)	8.5c (0.20)	20.0e (0.64)	7.2d (0.20)	4.0b (0.34)	80.7d (2.65)
0.05	32.5a (0.95)	5.0a (0.00)	4.2bc (0.22)	4.2bc (0.25)	8.7bc (0.13)	21.2d (0.56)	7.4d (0.17)	4.6a (0.21)	87.8c (2.32)
0.07	30.8b (0.53)	5.0a (0.00)	4.5ab (0.12)	4.5ab (0.14)	9.0b (0.37)	22.8b (0.49)	7.7bc (0.38)	4.6a (0.19)	88.9b (2.10)
0.10	32.2a (0.52)	5.0a (0.00)	4.6a (0.16)	4.8a (0.10)	9.5a (0.24)	23.5a (0.36)	8.2a (0.23)	4.6a (0.17)	92.4a (1.56)
0.40	31.0b (0.75)	5.0a (0.00)	4.5ab (0.21)	4.3bc (0.29)	8.6c (0.22)	22.7bc (0.39)	8.0ab (0.10)	4.6a (0.24)	88.7b (2.08)
0.60	31.0b (0.75)	5.0a (0.00)	4.5ab (0.30)	4.0c (0.17)	8.5c (0.33)	22.4c (0.29)	7.9ab (0.17)	4.6a (0.22)	87.9c (2.12)

[a] Values in parentheses are standard deviation of quality evaluation values for bread at each DATEM level. Values within a column with different letters are significantly different ($P < 0.05$). Standard error of mean at 6 degrees of freedom.
[b] At 7.11–7.40 mL/g, 26 points; 7.41–7.70 mL/g, 28 points; 8.01–8.30 mL/g, 32 points; >8.60 mL/g, 35 points.
[c] Favorable brown, 5 points; with spots, lackluster or nonuniform color, deduct 0.5 point; brown, 4 points.
[d] With perfect overall shape and size, crack-free, smooth, and without any spots, 5 points; with coarse crust or cracked, deduct 0.5 point; with good overall shape and size, smooth, and without any spots, 4 points.
[e] Milk-white and with luster, 5 points; without luster, deduct 0.5 point; white or yellowish-white, 4 points.
[f] Smooth, 10 points; somewhat coarse, 8 points.
[g] With perfect, minute, and elongated cells uniformly layered in with thin cell walls, sponge-like structure, 25 points; with good, minute, and elongated cells uniformly layered with somewhat thick cell walls, 24 points; with relatively uniform, elongated cells, somewhat thick cell walls, 23 points; with relatively uniform, round cells, somewhat thick cell walls, 21 points; with big, nonuniform, and mostly round cells, thick cell walls, 19 points.
[h] With perfect elasticity, rebound very quickly, 10 points; with good elasticity, rebound quickly, 8 points; with somewhat weak elasticity, rebound slowly, 6 points.
[i] Good mouthfeel, with favorable aroma 5 points; simple mouthfeel, without aroma or abnormal smell, 4 points.

TABLE V
Effect of DATEM on Farinograph Properties of Bread Dough[a]

DATEM Conc. (%)	Water Absorption Ratio (%)	Development Time (min)	Stability Time (min)	Softening Degree (BU)	Evaluation Value
0.00	62.2c	2.2a	10.9bc	48a	113d
0.03	63.2b	2.2a	10.8c	48a	114d
0.05	63.6a	2.0a	11.2b	44b	120c
0.08	63.1b	2.3a	12.2a	37c	130b
0.10	63.3ab	2.2a	12.4a	30d	138a

[a] Values within a column with different letters are significantly different ($P < 0.05$). Standard error of mean at 5 degrees of freedom.

TABLE VI
Effect of DATEM on Extensigraph Properties of Bread Dough[a]

DATEM Conc. (%)	Extensibility (mm)		Extended Resistance (BU)		Maximal Extended Resistance (BU)		Extended Ratio		Maximal Extended Ratio		Powdered Strength (cm^2)	
Standard[b]	45*	135*	45*	135*	45*	135*	45*	135*	45*	135*	45	135
0.00	156a	74b	436b	604b	633a	660a	2.8b	8.2c	4.1b	9.0c	117a	53a
0.03	109e	58c	294e	303e	389e	589d	2.7b	10.1b	3.6c	10.1b	52e	38c
0.05	125c	73b	445a	504c	597b	647b	3.6a	6.9d	4.8a	8.8c	93b	46b
0.08	135b	91a	387c	463d	524c	499e	2.9b	5.1e	3.9bc	5.5d	88c	47b
0.10	119d	50d	358d	610a	447d	623c	3.0b	12.2a	3.8bc	12.4a	66d	38c

[a] Values within a column with different letters are significantly different ($P < 0.05$). Standard error of mean at 5 degrees of freedom.
[b] * Indicates standard for proof time (min) of dough with DATEM.

with the increase of DATEM, which is in line with the reports on DATEM functionality (Stampfli and Nerden 1995). The largest specific volume and optimum crumb structure were obtained in the presence of 0.10% DATEM. When DATEM addition was at 0.05%, bread color, including skin color and crumb color, skin texture, smoothness, and mouthfeel improved, but as DATEM was increased further, skin color, skin texture, and mouthfeel showed no further improvement, while crumb color and smoothness of bread improved continuously. When DATEM was >0.10%, crumb color was relatively inferior but was still superior to that of the control, while the elasticity of bread was unchanged. As a whole, the optimum quantity of DATEM for making bread was 0.10%. The mechanism of the effects of DATEM on the quality of bread dough was almost the same as that on CSB dough, except for the volume.

Effects of DATEM on Properties of Bread Dough

The sensory analysis of bread showed that the optimal quantity of DATEM was at the 0.10% level. Similar to the evaluation of CSB dough quality, four bread dough samples with different DATEM additions (0.03, 0.05, 0.08, and 0.10%) were selected. Rheological properties were determined to verify the theoretical results above. The effects of DATEM on farinograph and extensigraph properties of bread dough are given in Tables V and VI.

It is clearly understood that DATEM significantly affected stability time, softening degree, and evaluation value overall, except for water absorption ratio and development time (Table V). When the addition was <0.03%, stability time, softening degree, and evaluation value were almost the same as those of the control, but when the addition was >0.03%, stability time, and evaluation value obviously increased, while softening degree decreased.

The effects of DATEM on extensigraph properties of bread dough are very complex (Table VI). Extensibility and powdered strength decreased, but extended resistance and extended ratio initially decreased and then increased.

Tables V and VI showed that adding DATEM had a significant effect on rheological properties of bread dough, so attention should also be paid to the quantity of DATEM during breadmaking.

The mechanism of the effects of DATEM on the rheological properties of bread dough is almost the same as that on CSB dough. Farvili et al (1997) reported that the effects of emulsifier on flours with different protein contents were varied.

Emulsifiers had a significant effect on flour with medium protein, so differences in specific volume and development time for CSB and bread dough with DATEM are possibly due to wet gluten contents or gluten index of the flours used. Development time was almost unchanged and stability time increased, which is not in accord with a former study that showed development and stability time changed little after DATEM was added (Stampfli et al 1996).

CONCLUSIONS

Through sensory evaluation and measurements of dough properties, the optimal quantities of DATEM for both CSB and bread were at the 0.10% level. However, the effects of DATEM on specific volume and development time of CSB and bread dough were different. Specific volume of CSB decreased slightly, while specific volume of bread increased. Development time of CSB dough was prolonged, while the effect for bread was not as obvious. The differences are possibly due to the different wet gluten contents or gluten index of the flours used (Farvili et al 1997) and this requires further research.

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