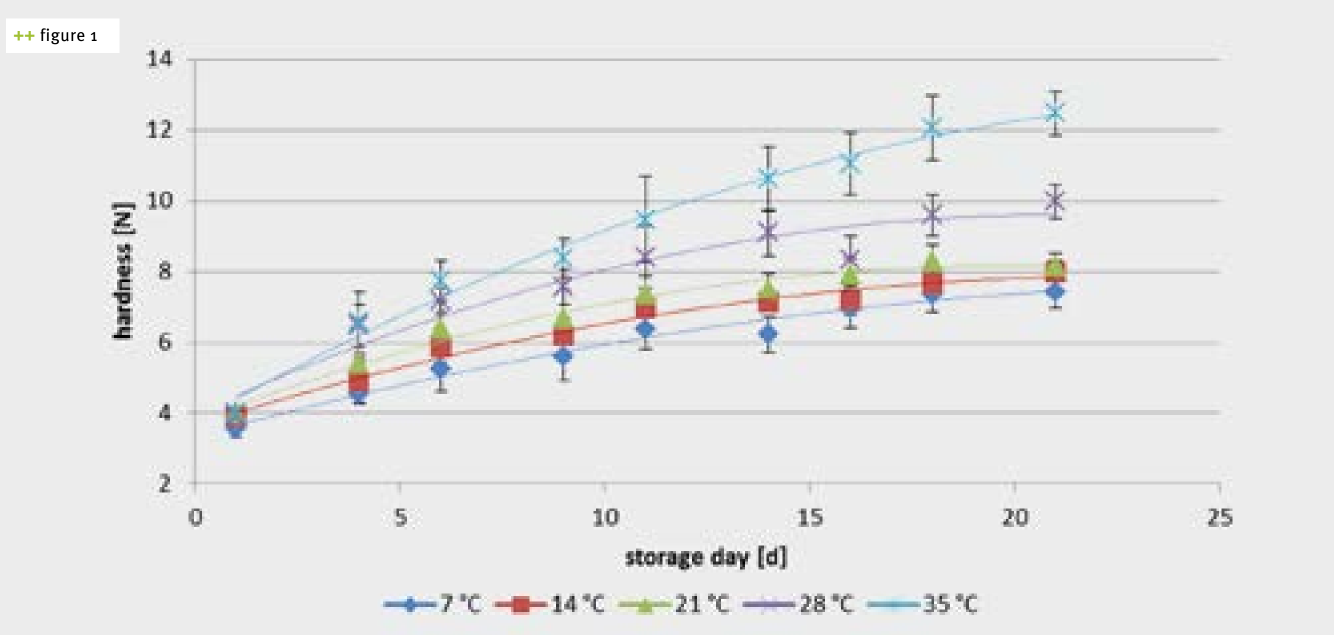
Pound cake quality as a function of time and temperature

THE PRESENT INVESTIGATIONS AT THE TECHNISCHE UNIVERSITÄT MÜNCHEN GIVE AN IMPROVED UNDERSTANDING OF THE INFLUENCE OF STORAGE TIME, TEMPERATURE AND ENZYMES ON POUND CAKE FIRMING BEHAVIOR



++ figure 1
Firming rate (hardening of the crumb texture over storage time) dependent on storage temperature. Mean (n = 4), ± sd.

The cake market has increased in Germany by approx. 12 % in the last decade. One of the main cake products, pound cakes, is traditionally consumed fresh and therefore storage behavior was not a quality concern to artisanal bakeries for a long time. With industrial processing, the requirement of long shelf life pound cake has increased. Besides aroma and microbiological stability, the main technological challenge is textural stability. Pound cakes are distinguished by their moist, soft and elastic crumb when fresh. On storage, cake crumb becomes dry, harder and loses its elasticity – this being the case in spite of placing the cake in gas and moisture impermeable packaging. The processes underlying the loss of freshness in cakes is known as staling and is chiefly caused by transport of moisture between the crust (crust absorbs water) and the crumb (crumb loses water) as well as by starch retrogradation [1, 2]. For bread crumb, it is well known that the staling behavior is accelerated at lower storage temperatures.

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Although the demand for pound cake with a long shelf life is high, information is scarce about the influence of storage temperature and time on pound cake staling as well as on the role of the lipid phase of cakes in staling. The main focus of this article is to analyze and characterize the impact of storage time and temperature on pound cake freshness via changes in crumb texture and cake moistness as well as to gain greater understanding of the staling process via microscopic studies of cake structure. This article also focuses on agents (enzymes) that affect the staling behavior positively.

To analyze the influence of different storage temperatures on pound cake texture, crumb hardness was measured by an instrumental texture analyzer. Pound cakes were prepared using a simple yet industrially relevant recipe (flour, fresh eggs, sugar, rapeseed oil, water, baking powder, emulsifier and salt) and processing protocol. After 2 h cooling cakes were packed in gas-impermeable bags with a CO_2/N_2 atmosphere and stored at 7, 14, 21, 28 and 35 °C. The different temperatures simulated different storage conditions: 7 °C for the fridge, 14–28 °C for maritime climate and 28–35 °C for subtropical and tropical climates. To prevent the influence of the different storage temperatures on cake hardness during analysis, cake loaves were equilibrated to room temperature (21 °C) 3 h before texture measurements. Crumb hardness measurements were performed at day 1, 4, 6, 9, 11, 14, 16, 18 and 21. All data were statistically evaluated by analysis of variance and treatment means compared by the Tukey's test (GraphPad Software, Inc., La Jolla, CA 92037 USA), with statistical significance set at $P < 0.05$.

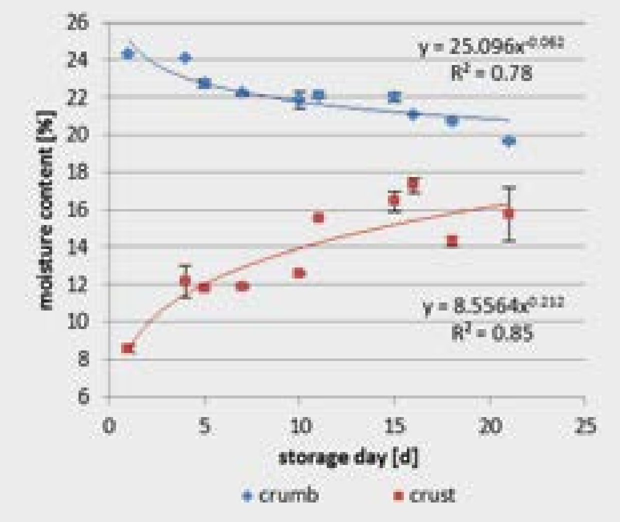
As demonstrated in figure 1, pound cake crumb hardness increased with increasing storage time. This is an expected finding. Additionally, and more interestingly, crumb hardness decreased with lower storage temperature. This last result is the opposite of what can be expected from bread, which stales (e.g., becomes harder) faster when stored at lower storage temperatures (i.e., under refrigeration). After 1 day storage, crumb hardness for cake stored at 35 °C was already approx. 12 % higher than for cake stored at 7 °C but the difference after 21 days was even higher, about 40 %. The results clearly showed that refrigeration has a significant ($p<0.01$) positive influence on slowing down the rate of staling of pound cake. However, refrigeration is a costly and often ill-suited solution to maintain freshness of industrial pound cakes.

To gain a deeper insight into pound cake firming, starch retrogradation measurements were performed during cake storage. Starch retrogradation is known to be the main reason for firming of bread and describes the aging process of starch after baking (on storage). During starch retrogradation amylose and amylopectin, the two polymeric fractions of starch, recrystallize and water is more tightly connected to them, particularly to amylopectin, over time. This phenomenon limits water's ability to contribute to the freshness perception of cakes and imparts a dry mouth-feel to cakes. The degree of starch retrogradation in the cakes was measured by Differential Scanning Calorimetry (DSC) as it is sensitive to the degree of crystallization of amylose and amylopectin. The DSC procedure has been used in the past in bread to support the view that starch retrogradation is accelerated by cooler storage temperatures (maximum at approx. 5 °C) [3].

For pound cake the crumbs were placed in DSC aluminum pans and measured by DSC. Retrogradation measurements, expressed as enthalpy changes (ΔH [J * g^{-1}TM]), were carried out at 7, 14, 21, 28 and 35 °C on days 1, 4, 6, 9, 11, 14, 16, 18 and 21 after baking. However, retrogradation was not detected at all temperatures during storage time. One reason may be attributed to the method, which was developed for bread but not cakes. Pound cake batter contains approx. 24 % flour (approx. 19 % starch) whereas wheat bread dough contains approx. 60 % flour (approx. 40 % starch), relative to the water added. Pound cake also contains additional ingredients such as egg, lipid (oil/fat) and sugar, which may interfere with starch gelatinization and therefore starch retrogradation measurements. To test this point further, retrogradation for cake flour-water suspensions stored at 5 and 35 °C for 5 days was measured by the same DSC method. Enthalpy peaks due to retrogradation were detected in all cases. The enthalpy peaks for 5 °C were approx. four times higher (4.36 ± 0.01 J * g^{-1}TM) than for the samples stored at 35 °C (1.00 ± 0.63 J * g^{-1}TM). Since the suspensions were made with flour and water only, results indicated that cake firming is driven not only by starch retrogradation, as is the case in bread, but also by other important effects (and interactions) due to other ingredients in cakes (eggs, oil/lipids and sugar).

The moisture contents of the crumb and crust were also measured during storage (up to 21 days) to understand their ▶

++ figure 2



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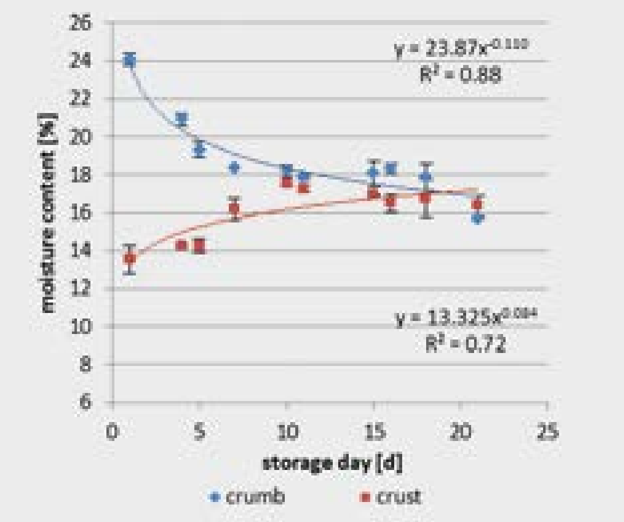
++ figure 2
Moisture content as a function of storage time (up to 21 d) between crumb and crust at 7°C. Mean (n = 2), ± sd.

++ figure 3



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++ figure 3
Moisture content as a function of storage time (up to 21 d) between crumb and crust at 35°C. Mean (n = 2), ± sd.

influence on cake firming rate (figures 2 and 3). The moisture content of cakes stored at 14, 21, 28 °C are between those of cakes stored between 7 and 35 °C (data not shown). The moisture content between the first day of the cake crust measured at 35 °C are approx. 5 % higher than at 7 °C. This could be attributed both to higher water activation energy and to higher water mobility. The activation energy is related to the freeing of bound water to the surrounding matrix and is non-linearly temperature dependent. This is due to the fact that the activation energy is proportional to temperature with an exponent relation (Arrhenius function). The water mobility describes the movement of the free water in the matrix, which is dependent on the moisture gradient in the matrix as well as on the temperature. Therefore the differences in moisture content are attributed to an increased moisture transport as well to the presence of a moisture transport adjusting to the equilibrium moisture between crumb and crust at higher temperatures (35 °C) as in contrast to lower temperatures (7 °C). This means that the moisture content for the crust at 7 and 35 °C for day 0 should be equal (virtual point).
No change in moisture transport was measured on day 1 in the crumb samples; at temperatures 7 and 35 °C both contain

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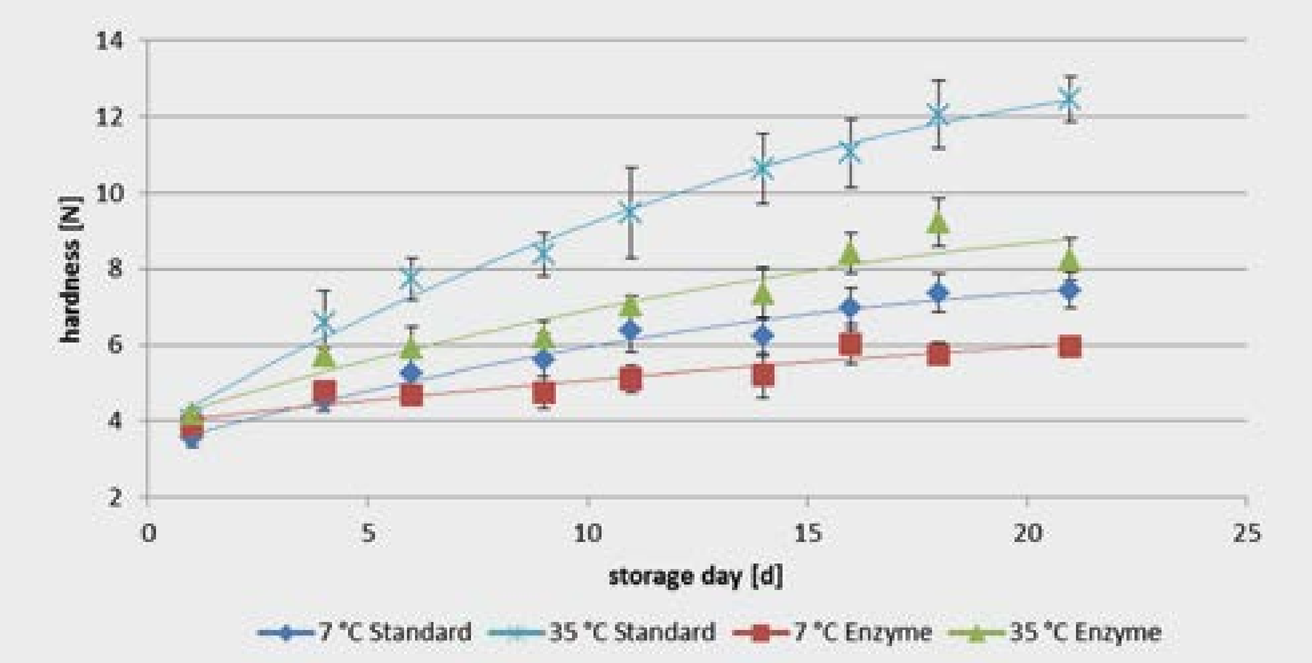

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++ figure 4
Firming rate (hardening of the crumb texture over storage time) dependent on storage temperature. Standard pound cake: Mean (n = 4), ± sd.; Enzyme pound cake: Mean (n = 2), ± sd.

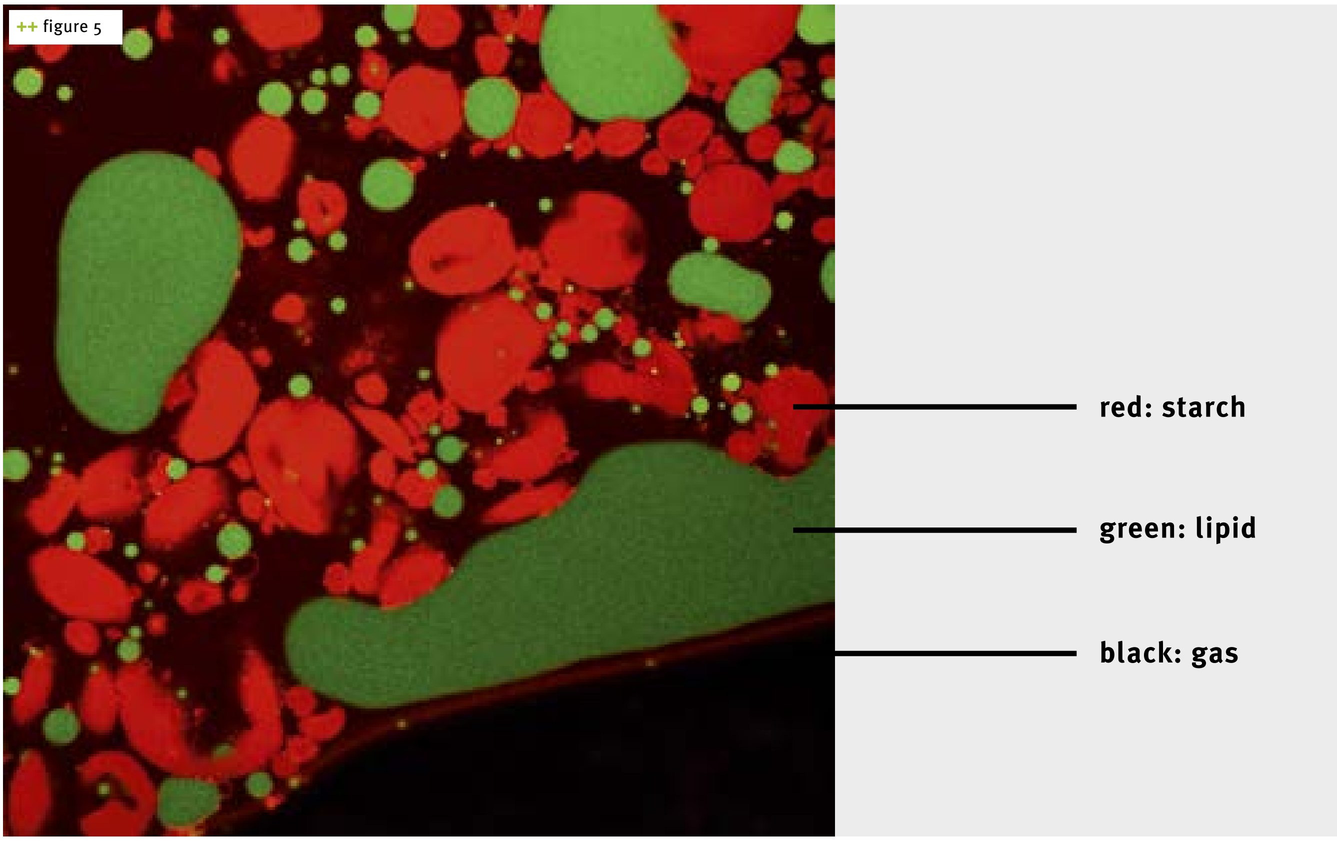
the same moisture content. Additionally, at this early stage (after the first day) the process of moisture transport across the center of the cake to the crust is still of very small magnitude and grows in the following days. Because of this, no change in moisture content is detectable between 7 and 35 °C on day 1. Furthermore, as mentioned earlier; the rate of moisture change with storage days at 35 °C is higher than at 7 °C due to the higher water mobility at 35 °C. Moreover, the moisture content between crust and crumb are similar at 17 % after 18 days, whereas for 7 °C, no equilibrium moisture content is reached within 21 storage days. The amount of crust moisture at 7 and 35 °C reaches the same content of approx. 17 % after a storage period of 21 days. This demonstrates that the moisture transport is supported at higher temperatures, especially in the crumb until equilibrium is reached. The results clearly show that the water mobility and therefore the temperature have an influence on the firming of pound cake.

According to these findings, moisture analyses for 7 and 35 °C were extended to 44 days. For the pound cake stored at 35 °C, the moisture content stayed at approx. 17 % and no further moisture transport was detected. For the pound cake stored at 7 °C, no adjustment in moisture between crust and crumb were detected within the storage period (data not shown).

To minimize the influences of firming, some possibilities are known: next to an increase in water absorbability of the crumb, for instance by using modified starch or emulsifiers, enzymes are becoming common processing aids today in cake to improve shelf life. Furthermore, in a variety of measurements the influence of lipid-modifying enzyme was tested. In addition to the major ingredients flour, egg and sugar, the lipid (fat/oil) content is also high. Lipids improve the batter stability during mixing and enhance the crumb softness and tenderness. Mono- and diglycerides are known to act as emulsifiers that encourage the suspension of one liquid in another as well as a gas in a liquid, and stabilize the liquid system as it occurs in the existing batter matrix [4, 5].

For the measurements, an enzyme (Novozymes OptiCake® Lift; 200 ppm) was added directly to the original recipe (to the flour) before mixing the batter, and this was followed by exactly the same procedure and testing protocol as described above. Figure 4 illustrates the influence of enzyme addition on pound cake crumb hardness at 7 and 35 °C storage temperature in comparison with the standard pound cake within 21 days. For both temperatures, a significant decrease ($p<0.01$) in crumb hardness was measured by the addition of enzymes over a time period of 21 days. It is clear that the enzyme slowed down the rate of hardening (staling) of cakes, with crumb hardness being decreased by approx. 20 % at 7 °C and 34 % at 35 °C in comparison to the no-enzyme pound cake. The firming rate of the crumb is defined as the increase of the regression lines of the crumb texture.

It was possible to relate the reduced crumb hardness due to enzyme addition to the stabilizing effect of the lipid-water system by emulsifiers produced in situ, which may influence moisture migration and to a smaller degree to an improved gas holding capacity and thereby to an increased cake volume, as is known to be the case for bread [6]. Another reason is the interaction of monoglycerides with starch. These interactions lead to formation of the so-called starch lipid complexes and occur after gelatinization, affecting the rate of retrogradation [7]. In detail, monoglycerides are able to form helical inclusion complexes with amylose which prevent the amylose and in doing so perhaps to some degree amylopectin from re-crystallizing. As known from the literature for different kind of starches, the effect of emulsifier to lower retrogradation measured via DSC is greater at higher temperatures [8]. ▶



++ **figure 5**
Micrograph of pound cake crumb. Size: 215 x 215 µm (1024x1024 px); magnification: 60x

The effect of the chosen lipid-modifying enzyme on the moisture transport, retrogradation and lastly on the firming behavior of pound cake is currently being pursued.

Furthermore, the effect of the phospholipase on the fat phase was studied via changes in the fat droplet size and its distribution in pound cake crumb by confocal scanning laser microscopy (CLSM). Using CLSM, ingredients such as starch, protein and lipid can be visualized without special sample preparation. Therefore, the original structure is not influenced, which is necessary to evaluate the effects of different sample preparations on the crumb matrix microstructure. Figure 5 exemplifies in detail a typical pound cake crumb structure. The starch fraction is shown in red and the lipid fraction in green. CLSM images are being used in an ongoing investigation to help understand the influence of the sample treatment on cake firming behavior. Results so far have indicated that the fat droplet size distribution in cake is not constant over time but is rather dynamic. One of the most important points will be to analyze whether the dynamics are influenced by the action of the phospholipase in lipids.

Firming of bakery products such as pound cakes is still a significant commercial problem. Although the firming process is clearly affected by moisture transport due to the moisture gradient between crumb and crust, this investigation indicates that starch retrogradation as well as reorganization of the lipid structure in the crumb are important underlying actors driving staling and loss of quality of cakes on storage.

References

1. Gray, J.A. and J.N. Bemiller, Bread Staling: Molecular Basis and Control. Comprehensive Reviews in Food Science and Food Safety, 2003. 2(1): p. 1–21.
2. Seyhun, N., G. Sumnu, and S. Sahin, Effects of Different Starch Types on Retardation of Staling of Microwave-baked Cakes. Food and Bioproducts Processing, 2005. 83(1): p. 1–5.
3. Zeleznak, K.J. and R.C. Hoseney, Characterization of Starch from Bread Aged at Different Temperatures. Starch – Stärke, 1987. 39(7): p. 231–233.
4. Richardson, G., et al., Microstructure of α-Crystalline Emulsifiers and Their Influence on Air Incorporation in Cake Batter. Cereal Chemistry Journal, 2002. 79(4): p. 546–552.
5. Jyotsna, R., et al., Improvement of Rheological and Baking Properties of Cake Batters with Emulsifier Gels. Journal of Food Science, 2004. 69(1): p. SNQ16–SNQ19.
6. Jekle, M. and T. Becker, Effects of Acidification, Sodium Chloride, and Moisture Levels on Wheat Dough: II. Modeling of Bread Texture and Staling Kinetics. Food Biophysics, 2012. 7(3): p. 200–208.
7. Fredriksson, H., et al., The influence of amylose and amylopectin characteristics on gelatinization and retrogradation properties of different starches. Carbohydrate Polymers, 1998. 35(3–4): p. 119–134.
8. Eliasson, A.-C. and G. Ljunger (1988). "Interactions between amylopectin and lipid additives during retrogradation in a model system." Journal of the Science of Food and Agriculture 44(4): 353-361. +++

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