Effects of Starch-based Anti-caking Agents on the Functional Properties of Shredded Mozzarella Cheese

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ABSTRACT

Mozzarella cheese production has been gaining market share due in part to increasing market for pizza and ready to eat food items. Anti-caking agents are utilized in the production of shredded cheese for reducing clumping and increasing the appearance of separate cheese shreds. Six anti-caking agents were applied to low moisture part skim Mozzarella cheese and examined for effects on three major functional properties of Mozzarella cheese; meltability, stretchability, and free oil formation. Meltability determination utilizing a fabricated UW Meltmeter resulted in no significant differences between untreated samples (control) and samples treated with anti-caking agents containing cellulose, potato starch or mixtures including dextrose. Stretchability measurements taken using a modified helical viscometry procedure also resulted in no significant differences between control and treated samples. Significant differences were found when comparing free oil percentages obtained from varying treatments of anti-caking agents. A mixture of potato starch and cellulose resulted in the lowest level of free oil among all samples tested.

Because potato starch treated samples performed equally to cellulose treated samples in both meltability and stretchability testing, anti-caking agents containing potato starch could be considered as an alternative to cellulose-based anti-caking agents. In addition, the use of potato starch alone and in conjunction with powdered cellulose has been shown to be more effective for free oil control. By treating with potato starch, functional

properties of shredded Mozzarella cheese have been positively altered in a way which may increase acceptability by consumers.

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CHAPTER I

INTRODUCTION

Consumers expect high quality shredded cheese starting from package appearance to acceptable performance during baking. Flowability and appearance of individual cheese shreds are important properties of unheated Mozzarella cheese (Kindstedt, 1995). The functionality of heated Mozzarella cheese depends on several factors: meltability, stretchability, free oil formation, and browning. These properties play heavily on consumer perceptions of cheese quality (Rowney et al., 1999; McMahon and Oberg, 1998; Pilcher and Kindstedt, 1990).

In order for producers to deliver high quality shredded Mozzarella cheese, the introduction of processing aids, such as anti-caking agents has become essential for increased flow and maintenance of separate cheese shreds. Interactions between particles, as well as the moisture and fat content of the product can result in reduced product flowability (Onwulata et al., 1996). Anti-caking agents can enhance product flow and reduce clumping by limiting cohesiveness and compression normally found during packaging and shipping of shredded cheese products (Onwulata et al., 1996). Little research has been completed regarding the specific effects of anti-caking agents on the functional properties of heated shredded Mozzarella cheese.

Cellulose based anti-caking agents, specifically powdered cellulose, are most common in the cheese packaging industry (McGinley and Thomas, 1980). Benefits of this processing aid include the ability to stabilize both oil and water phase ingredients and disperse evenly on cheese shred surfaces (FMC Biopolymer, 2002; McGinley and Thomas, 1980). Due to the large particle size of the product, cellulose based anti-caking agents have a tendency to leave white discolorations on the surface of the cheese shred. Powdered cellulose has a dry, dusty consistency which can lead to problems in a manufacturing setting.

As a result, starch based products were introduced as substitutes for cellulose based adjuvants. Reddy (1997) found that rice flour eliminated the white discoloration found on cheese surfaces. The use of a flour based anti-caking agent has been determined to increase the functionality of the processing aid, specifically with regard to tenderness and melt (Reddy, 1997). In addition to rice flour, potato starch has been identified as contributing a 'clean' flavor when added to food components (J. Hicks, 2002, written communication). The higher moisture content found in potato starch also can be used to overcome issues of dusting during production.

The addition of starch based anti-caking agents to existing cellulose based products may provide a functionally superior and cost effective alternative to traditional cellulose based anti-caking agents. The increased moisture contained in potato starch added to the existing cellulose product should enhance the properties of both ingredients and increase the functionality of the anti-caking agent.

The effect on cheese functional properties when altering the ingredients of the anti-caking agent is the main focus of this research. Three main functional properties of shredded Mozzarella cheese will be analyzed: meltability, stretchability (apparent viscosity), and free oil formation.

CHAPTER II

REVIEW OF LITERATURE

Industry Aspects

Production of cheese in the United States has been steadily increasing for the past fifteen years. According to the International Dairy Foods Association, a total of 7.9 billion lbs. were produced in the U. S. in 1999 and, in 2000, cheese production increased 4.8% to 8.3 billion lbs. Italian style cheese represented about 40% of the total natural cheese production in 1999, up 4.6% from 1998. Mozzarella comprises 80% of all Italian style cheeses produced in the U.S. Increase in Mozzarella production is due in part to the expansion of the pizza industry (IDFA, 2001).

Mozzarella is categorized as a pasta filata style, semi-hard variety of cheese. Guidelines set by the USDA state that a low moisture part skim Mozzarella shall contain between 45% and 52% moisture and between 30% and 45% milkfat on dry basis (USDA, 1980). Low moisture part skim Mozzarella is most commonly utilized in the pizza industry due to its exceptional properties of meltability, stretchability and elasticity. Additional regulations for allowing ingredients of low moisture part skim Mozzarella cheese are detailed in the Code of Federal Regulations, 21CFR 133.158 (USDA, 1998).

Influence of Milk Structure on Cheese Formation

Milk has been categorized as a colloidal suspension of casein micelles. The conversion of milk from this suspension into cheese begins with the formation of curds resulting from a three step process: acidification, coagulation, and dehydration (Fox et. al., 2000).

Acidification of the colloidal suspension affects coagulant activity, level of residual coagulant in the curd, curd strength, gel syneresis, and the extent of dissolution of calcium phosphate. pH must be properly monitored to achieve the desired functional properties of the cheese product (Barbano, 1999; Fox et al., 2000). Acidification of milk can be performed using several techniques. Inoculation using lactic acid producing bacteria or direct addition of an organic acid are both common methods used in Mozzarella cheese production. Kindstedt et al. (2001) concluded that altering the pH of Mozzarella post production significantly affected melt characteristics and calcium distribution. Additionally, alteration of pH levels at various production stages has been found to significantly affect cheese composition and water holding capacity as well as functionality of the melted cheese product (Guinee et al., 2002).

Coagulation occurs once the external submicelles that contain surface κ-casein are hydrolyzed by action of rennet (resulting in the formation of para-κ-casein and glyco-macropeptides) to expose the calcium sensitive α_{s1}, α_{s2} and β-caseins located toward the interior of the micellar structure (Hill, 1995). Once this micelle stabilizing protein has been removed, internal submicelles are unable to prevent aggregation with each other due to the loss of steric stabilization and begin to form a coagulum. Calcium ions play an integral part in the coagulation of micelles. An increase in calcium concentration can increase the occurrence of coagulation even at a lower degree of κ-casein hydrolysis (Fox and McSweeney, 1998). In addition, a reduction in colloidal calcium phosphate can prevent coagulation from occurring altogether. Temperature also plays a factor in coagulum formation. Fox and McSweeney (1998) indicate that no coagulation will occur below 20°C regardless of degree of hydrolysis and calcium concentration.

Upon acidification and coagulation, a fine gel network is created through the incorporation of fat globules, serum, and bacterial cells into the protein matrix. The amount of residual coagulant and native milk proteases present in the product plays a large role in altering functional properties of cheese. Once the gel matrix has been established, a significant increase in viscosity can be noted (Fox et al., 2000).

Oberg et al. (1993) observed that milk proteins align into fibers separated by channels containing closely packed fat globules, bacterial cells, and whey serum. In a warm state (55°C), fat globules are fluid and appear smooth in the observed channels. As the cheese cools (to 4°C), fat globules become rigid while the protein matrix conforms to the shape of the solidified globules (McMahon and Oberg, 1998). Because of this action, fat appears to function as an interrupting agent for fusion of the protein matrix during cooking and stretching stages thereby allowing retention of excess serum (McMahon et al., 1999).

Dehydration occurs once cheese curds have been cut and whey is expelled. Casein and fat are concentrated during this process which is affected most significantly by Ca^{2+} and casein concentrations, pH of the whey, and duration of the event (Fox et al., 2000). The extent of syneresis is one of the major factors in determining cheese variety.

Importance of Mozzarella cheese structure on functional properties

Key functional properties of melted Mozzarella cheese, namely meltability, stretchability, free oil formation, and browning are highly dependent on the underlying cheese structure and composition. Moisture content, percentages of fat, salt, and minerals (calcium specifically) as well as pH and extent of proteolysis dictate the resultant functionality of the cheese (Yun et al., 1993a; Farkye et al., 1991; Rowney et al., 1999; McMahon and Oberg, 1998; Kindstedt and Guo, 1998; Metzger et al., 2001; Guinee et al., 2002). Additionally, critical processing control steps such as control of protein to fat ratio, pH at whey draining, stretching temperature, and final temperature of cooling after molding are necessary in order to achieve a consistent cheese product (Barbano, 1999).

Meltability

Kindstedt (1993) defined meltability as the ability of cheese particles to flow together and form a continuous melted mass. The overall meltability of Mozzarella cheese can be determined by two factors: fat content and protein-protein interactions with water trapped within the protein matrix (McMahon et al., 1999). Several researchers have determined that the status of the protein matrix plays the largest role in controlling melting properties of Mozzarella cheese (Guo et al., 1997; McMahon and Oberg, 1998; McMahon et al., 1999). Their findings indicate that during aging, proteins absorb entrapped serum from the matrix thereby decreasing aggregation and increasing melt. These results occur as water is transferred from the fat-serum channels to the protein matrix as a result of decreased hydrophobic interactions within the protein matrix (McMahon et al., 1999).

McMahon and Oberg (1998) also noted from micrographs that no changes were evident in fat globule positions, only changes in protein and water distribution affected cheese microstructure.

The protein-serum interaction is further enhanced by the addition of NaCl and a reduction in calcium. NaCl was found to be critical to the solubilization of intact caseins during aging (Guo et al., 1997). It also has been noted that the addition of salt to cheese results in a more evenly dispersed protein appearance (reduced aggregate size and spacing) (McMahon and Oberg, 1998). The energy required to disrupt the casein matrix in an unsalted, non fat Mozzarella cheese is greater due to highly aggregated proteins which have been found to decrease the meltability of the cheese (Paulson et al., 1998).

In addition to NaCl content, calcium dramatically affects the meltability of Mozzarella cheese. Decreased calcium levels increase melt at cheese pH 5.3 (McMahon and Oberg, 1998). Reducing the calcium to casein ratio allows for increased moisture and greater proteolysis thereby increasing the cheese melt characteristic. Guinee et al. (2002) concluded that alteration of pH and calcium concentrations could be used as a method for controlling the functional properties of Mozzarella by optimizing the extent of proteolysis over time.

Modifications of fat content also have been found to affect meltability of altered Mozzarella cheese. Decreased fat content in Mozzarella cheese does not appear to affect the melt characteristics when moisture content is increased (Fife et al., 1996), while unaltered reduced fat cheeses did possess differences in meltability (Rudan et al., 1999). Homogenization of milk prior to cheese-making decreased Mozzarella cheese meltability as a result of buffering of smaller fat globules in the casein matrix (Tunick, 1994). Yun et al. (1998) found that incorporation of an economically acceptable substitute to fresh milk (nonfat dry milk) into low moisture part skim Mozzarella cheese did not significantly impact meltability. Rudan et al. (1999) suggest that the use of a hydrophobic surface coating agent will provide appropriate melt characteristics to low fat Mozzarella cheese during pizza baking.

Some alterations in manufacturing and storage conditions have been determined to affect Mozzarella meltability. Frozen samples aged between 14 and 21 d resulted in no loss in cheese melt quality of shredded low moisture Mozzarella cheese (Bertola et al., 1996; Viotto and Grosso, 1999). High screw speeds used during the stretching process significantly lowered the meltability of the cheese due to reduced moisture levels and fat on dry basis levels (Renda et al., 1997). Substituting rice flour and modified starch products for cellulose as the main ingredient in anti-caking agents resulted in improved meltability when blended with bentonite and polydimethyl siloxane (Reddy, 1997). Meltability has been measured using a variety of techniques with little compatibility among methods. The Arnott (Arnott et al., 1957) and Schreiber tests (Kosikowski, 1977) are based on heating cheese samples and recording height decrease and diameter expansion respectively. No standard amounts or heating parameters were established for these methods. A modification of the Schreiber test (Muthukumarappan et al., 1999) uses a specified range of heat (60 - 90°C) and measures area of melt as opposed to diameter. This process has only been proven effective for regular fat cheeses however.

Park et al. (1984) compared several procedures for cheese meltability and concluded that both rheological and thermal characteristics must be taken into consideration when determining melt. The University of Wisconsin (UW) meltmeter was created as a lubricated squeeze-flow device for measuring melt/ flow characteristics of varying fat levels in cheese under constant temperature (Wang et al., 1998). Results from this apparatus produce values consistent with calculated theoretical values. The UW meltmeter was further modified to allow for determination of softening point during transient temperatures (Muthukumarappan et al., 1999). Both devices account for rheological/ flow and thermal/ heat transfer characteristics of melted cheese.

Stretchability

Stretchability encompasses the tendency of an object to form elongated fibrous strands that do not break when pulled (Kindstedt, 1993). This unique property of pasta filata type cheeses, such a Mozzarella, makes it very desirable for use in pizza applications

(Guinee and O'Callaghan, 1997). When describing cheese, apparent viscosity (AV), the combination of stretchability and elasticity ("strength of stretch"), is often used for a more complete understanding of this characteristic.

During cheese formation, cheddared curd is heated into a plastic molten mass. Plasticization requires alignment of the paracasein matrix and coalescence of fat and moisture into elongated pools parallel to the protein fibers (Fox et al., 2000). Alignment of curd fibers occurs during the kneading and stretching stage of production. Researchers have suggested that curd pH, draw pH, and colloidal phosphate content play an important role in stretchability of Mozzarella cheese (Lawrence et al., 1987; Kiely et al., 1993; Guinee et al., 2002). Once protein alignment has occurred, typical functional characteristics are obtained. Mead and Rupas (2001) discovered that the addition of denatured whey protein at 0.4% will produce cheese with an AV considerably greater than standard milk Mozzarella cheese and therefore would exhibit unacceptable stretch properties.

AV has been found to decrease rapidly, and then stabilize over time during refrigerated storage (Bertola et al., 1996). These results are probably due to the occurrence of proteolysis within the system (Kindstedt et al., 1992). As a result of ageing, the casein matrix porosity increases due to proteolysis and therefore exhibits less resistance to stretching (Bertola et al., 1996; Tunick et al., 1997).

Difficulties arise when trying to measure rheological properties of melted cheese. Industry tends towards using empirical tests such as the "fork test" because of its simplicity (USDA, 1980). While this type of information is useful for the location performing the test, the fork test is highly subjective and requires experience on the part of the tester. Also, results do not correlate with other findings. Researchers have tried to produce more fundamental results using a variety of testing procedures.

Kindstedt and Kiely (1992) found that using helical viscometry successfully measured AV when surface cooling and moisture loss were minimized. Cavella et al. (1992)

established that spinning tests can be successfully used to evaluate extensibility and melt in Mozzarella. Another method examined utilizes a vertical uniaxial extension apparatus as a method for quantifying stretchability (Ak et al., 1993). Further still, Apostolopoulos et al. (1994) developed both fundamental and empirical tests that relate well to industry and consumer practices. A Nene Universal Testing Machine was used with differing set-ups for each type of test. Recently, Guinee and O'Callaghan (1997) developed a method for analysis of stretch using uniaxial extension in combination with conditions typically found by the consumer. All of these tests appear to produce appropriate results but no conclusive evidence exists as to which method provides the most accurate information.

Free Oil Formation

Free oil (FO) formation, also known as oiling off or fat leakage, occurs during the heating of Mozzarella cheese. Release of oil results from the collapse of the casein matrix allowing fat globules to coalesce and migrate to the surface where pools of FO are formed (Tunick, 1994; Rowney et al., 1999). Explanations for the variability of FO formation observed from different types of Mozzarella cheese have been the focus of some research. Fat globule size, location within the casein matrix, and degree of agglomeration all are related to the formation of FO in Mozzarella cheese (Rowney et al., 1998). A correlation between fat globule size and degree of agglomeration exists for emulsion stability of the globule and interaction of the fat/water interface (Oberg et al., 1993, Cano-Ruiz and Richter, 1997). In addition, the melting profile of milkfat used in cheese production has been correlated with FO content of Mozzarella (Rowney et al., 1998).

An alteration of the polymorphic structure of cheese has been seen when emulsifying salts are added to Mozzarella cheese (Tunick et al., 1989). Kindstedt et al. (1992) determined that a low salt content in Mozzarella cheese results in an increase in FO formation caused by reduced emulsification of fat by casein due to less sodium/ calcium exchange. Conversely, an increase in salt would decrease the fat leakage during melting.

Kindstedt and Rippe (1990) detailed a decrease in FO formation after refrigerated storage as a result of proteolysis while Apostolopoulos et al. (1994) found a significant increase in the amount of FO when samples were frozen. Homogenization also decreases the formation of FO due to increased emulsification caused by decreased fat globule size (Tunick, 1994; Rudan et al., 1998). Tunick (1994) also states that when fat is not homogenized, FO formation is dependent on proteolysis.

Traditionally, FO formation was measured by melting cheese on filter paper to achieve an oil ring. The resulting ring size related to the amount of free oil in the cheese product (Breene et al., 1964). Kindstedt and Rippe (1990) found this process to be time consuming and so devised a method using a modified Babcock procedure to quantify FO based on either percentage in cheese or percentage on a total fat basis (FOFB). This test provides good reproducibility and utilizes common equipment available in dairy facilities. A modified Gerber test was also devised for European counterparts (Kindstedt and Fox, 1991).

Effects of Manufacturing and Storage on Mozzarella

Manufacturing and storage of Mozzarella cheese play an important role in the development of characteristic properties of cheese. Fox et al. (2000) list major factors related to manufacturing that affect physical properties of Mozzarella: salt, pH, fat, and moisture. Sodium in the serum phase is thought to induce swelling of the protein matrix which increases both water-binding capacity and solubilization of caseins in the matrix (Kindstedt and Guo, 1997). pH affects the integrity of the colloidal calcium phosphate and casein micelles (Rowney et al., 1999; Kindstedt et al., 2001; Guinee et al., 2002; Feeney et al., 2002). Changes can disrupt binding sites on the casein molecule and ultimately alter the structure of the matrix. pH variations at different stages of production also affect overall product quality (Kiely et al., 1993; Yun et al., 1993a; Guinee et al., 2002; Feeney et al., 2002). Fat content relates heavily to melt and free oil formation. Kindstedt and Rippe (1990) found that increased fat content in cheese can result in excessive oiling off when melted while a lack of available fat can produce tough and rubbery melted cheeses (McMahon et al., 1993). Moisture can be affected by high oven temperatures (Yun et al., 1993b), salt content (Kindstedt et al., 1992 and McMahon and Oberg, 1998), and manufacturing processes such as screw extrusion speed (Renda et al., 1997).

Storage or aging of Mozzarella cheese provides most of the desired functional characteristics. Proteolysis, caused primarily by residual coagulant and endogenous proteases is considerable within the first two weeks of storage (Barbano et al., 1993). Marked change in cheese microstructure over time has been noted by several researchers (Kiely et al., 1993; McMahon et al., 1993; Tunick et al., 1997; Guinee et al., 2002) indicating a dissociation of casein micelles to form noncolloidal protein complexes caused by conversion of dicalcium paracaseinate to monocalcium phosphate. Initially, Mozzarella is tough, nonhomogeneous, and possesses a very elastic consistency caused by lack of FO release and separation of free water (Kindstedt, 1995). After 21 days the cheese becomes more pliable, uniform in appearance, and more fluid as a result of destruction of casein components of the cheese (Kiely et al., 1993). Extensive aging (>50 days) of cheese results in an excessively soft texture and increased FO formation thereby making it unsuitable for use on pizza (Kindstedt, 1995).

Structural and functional differences between cellulose and starch

Cellulose

Cellulose is derived from structural material in plant tissues and contains repeating units of cellobiose connected by β-1→4 linkages. In native form, cellulose is a fibrous elongated molecule consisting of about 3000 units that retains its structure even in solution. Because of the β-linkage, humans are unable to digest this material. Cellulose derivatives have been created to produce a more functionally acceptable product.

Powdered cellulose is the most common type of derivative of cellulose used for the production of anti-caking agents for the shredded cheese industry. Controlled acid hydrolysis of the amorphous regions of the cellulose fibers results in the formation of sponge-like microcrystals of 20-90μm particle size (Fennema, 1996). These microcrystals are further processed by spray-drying to create the powdered form used primarily as cellulose based anti-caking agents. Modification results in an odorless, colorless, tasteless product. Functional properties of powdered cellulose include its ability to stabilize dispersed oil such as found on the surface of cheese products, and distribute uniformly onto cheese surface due to large particle size (McGinley and Thomas, 1980). Reddy (1997) indicated that the large particle size of cellulose resulted in functionally acceptable shredded cheese, but created a noticeably white coating on the shred surface, an undesirable trait to consumers.

Starch

Starch molecules are composed of a combination of D-glucose polymers consisting of both amylose (linear) and amylopectin (branched) structures. Linear portions of both chains are connected via an α-1$\rightarrow$4 glucosidic bond while branched sections contain α-1$\rightarrow$6 linkages (deMan, 1999). Because of these linkages, starch is digestible to humans. Different structural elements provide the wide range of functional properties associated with different starch varieties. For example, potato starch has a large granule size while rice starch exhibits a significantly smaller granule but both contain mainly amylopectin fractions. In native state, starch molecules have very highly ordered structures and are insoluble in cold water. Granule sizes range from 2μm for rice starch up to 130μm for Australian arrowroot (Snyder, 1984).

The structure of potato starch is unique in that it contains phosphate derivatives instead of phospholipids generally found in cereal starches. Attached phosphate derivatives cause the starch to carry a negative charge thereby repelling one another and increasing viscosity and clarity (Jane, 1997). Potato starches exhibit excellent binding power as indicated by its use as a dusting agent in conjunction with powdered sugar for candies (Mitch, 1984).

Anti-caking agents

In order to increase the functionality of shredded cheese products, anti-caking agents were introduced as processing aids. Peleg and Hollenbach (1984) speculate that some of the mechanisms by which anti-caking agents function include physical separation, lubrication, competition for adsorbed water, and cancellation of electrostatic charges and molecular forces. Anti-caking agents prove effective when applied to the surface of the product so that the majority of particle interactions occur between anti-caking agent particles, not between the product surface (Peleg and Hollenbach, 1984).

The Code of Federal Regulations states that silicate based anti-caking agents can be added to products at a level no greater than 2% (w/w) to improve processing of the product. However, no specific regulations exist for the use of cellulose or starch based anti-caking agents on shredded cheese products. Commonly utilized anti-caking agents have been classified as Generally Recognized As Safe (GRAS).

In addition to cellulose and starch based anti-caking agents, several other anti-caking agents or flow conditioners are utilized in the food industry. Main food grade conditioners include silicon dioxide, silicates, phosphates, salts of stearic acid, and talcum (Peleg and Hollenbach, 1984). Each agent can be functionally altered to provide the desired characteristics for the application. Typical products that would utilize these agents include sugars, salts and spices, cake and dessert mixes, and dairy product sauces.

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CHAPTER III

EFFECTS OF ANTI-CAKING AGENTS ON THE FUNCTIONAL PROPERTIES OF SHREDDED MOZZARELLA CHEESE

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ABSTRACT

Mozzarella cheese production has been gaining market share due in part to increasing market for pizza and ready to eat food items. Anti-caking agents are utilized in the production of shredded cheese for reducing clumping and increasing the appearance of separate cheese shreds. Six anti-caking agents were applied to low moisture part skim Mozzarella cheese and examined for effects on three major functional properties of Mozzarella cheese; meltability, stretchability, and free oil formation. Meltability determination utilizing a fabricated UW Meltmeter resulted in no significant differences between untreated samples (control) and samples treated with anti-caking agents containing cellulose, potato starch or mixtures including dextrose. Stretchability measurements taken using a modified helical viscometry procedure also resulted in no significant differences between control and treated samples. Significant differences were found when comparing free oil percentages obtained from varying treatments of anti-caking agents. A mixture of potato starch and cellulose resulted in the lowest level of free oil among all samples tested.

Because potato starch treated samples performed equally to cellulose treated samples in both meltability and stretchability testing, anti-caking agents containing potato starch could be considered as an alternative to cellulose-based anti-caking agents. In addition, the use of potato starch alone and in conjunction with powdered cellulose has been shown to be more effective for free oil control. By treating with potato starch, functional properties of shredded Mozzarella cheese have been positively altered in a way which may increase acceptability by consumers.

Key words: Mozzarella, anti-caking agents, functional properties, starch

INTRODUCTION

The market for Mozzarella cheese has significantly increased over the last fifteen years. Italian style cheese, of which 80% is Mozzarella, represented 40% (3.16 billion lbs) of total cheese production in 1999 (IDFA, 2001). In order to comply with this increasing demand, better understanding of the functional properties native to Mozzarella is required.

Anti-caking agents are common adjuncts used in the cheese industry to prevent clumping of cheese shreds during packaging, shipping, and storage. These adjuncts typically contain cellulose because of excellent surface coating and ability to maintain an effective oil/ water boundary (McGinley and Thomas, 1980). Starch based anti-caking agents are also known to have properties that would be beneficial when used in this capacity. Rice starch has been shown to reduce the appearance of white discolorations commonly found while using powdered cellulose (Reddy, 1997). Potato starches specifically exhibit excellent binding power and impart desirable flavor characteristics which contribute also to the desire to modify existing formulations (Mitch, 1984). The high water content found in potato starches also can reduce excess dusting during applications (Whistler, 1984).

Additional anti-caking formulations have been created to further increase the functionality of the product. In an effort to help reduce the growth of microorganisms and level of oxidation in cheese, modifications of the package atmosphere have been reviewed. The use of enzymes as oxygen scavengers has been successfully demonstrated (Mistry and Min, 1992; Isaksen and Adler-Nissen, 1997). Glucose oxidase has been used to this extent, but requires a sufficient glucose source in order to complete the reduction of oxygen. Inclusion of dextrose along with glucose oxidase into anti-caking formulations would further increase the functionality of anti-caking agents (J. Hicks, 2001, written communication).

Increased functionality of anti-caking agents should help to improve the functional properties of unheated as well as melted Mozzarella cheese. Melt, stretch and free oil formation are three of the most important factors to review when looking at functional properties of melted Mozzarella cheese. Meltability describes the degree with which cheese shreds are able to melt and flow together. Proper degree of melt can be achieved by carefully monitoring pH, calcium and phosphorus levels, and extent of aging (Barbano, 1999; Rowney et al., 1999; Guinee et al., 2002). Fat content also plays a significant factor in meltability. Increased fat content prevents casein aggregates from interacting with each other thereby producing a weaker protein matrix (Johnson, 2000). Stetchability has been detailed as the expected "chewiness" of the cheese. Alteration of pH affects the ability of cheese curds to plasticize in hot water and ultimately stretch during production (Kimura et al., 1992). A reduction in fat can also negatively impact the chewiness of melted cheese (Metzger and Barbano, 1999). Free oil formation plays an important role in the acceptability of products containing melted Mozzarella cheese. A lack of free oil will result in reduced sheen, surface dehydration and excessive browning (Yun et al., 1993). Skin formation can also occur as a side effect of a lack of free oil formation during melting (Rudan et al., 1998). Excessive oil will make a product appear higher in fat resulting in a negative consumer opinion (Kindstedt and Rippe, 1990).

The growing market for Mozzarella cheese and increasing industry need for improved cheese functionality have increased attention on this food product. A method for improving the inherent functional properties of cheese by altering the composition of the processing aid would be a highly desirable commodity to the pizza and ready to eat food industry. Analysis of the effects on meltability characteristics, stretchability and apparent viscosity, as well as maintaining acceptable levels of free oil will help to ensure good product quality, and ultimately, consumer satisfaction of the product. Limited data is currently available regarding the effects of anti-caking agents on Mozzarella cheese and what, if any, functional changes occur in the cheese due to compositional alterations of the anti-caking agent. The focus of this research is to determine whether or not modifications to anti-caking agents including the use of potato starch alone and in combination with cellulose will affect the characteristics of melt, stretch, and free oil formation in melted Mozzarella cheese.

MATERIALS AND METHODS

Sample Preparation

Low moisture, part skim (LMPS) Mozzarella cheese was obtained commercially (Alto Dairy Cooperative, Waupun, WI) in 20 lb blocks. Alto Dairy Cooperative provided exact information regarding the manufacture and ship dates of the newly made cheese to ensure uniformity of age. Cheese was aged for 7d at 4°C then shredded (±2d) using a Hallde Shredder, type RG-7 (AB Hallde Makiner, Kista, Sweden) in preparation for addition of anti-caking agents. All shredded cheese was commingled before addition of anti-caking agents to guarantee uniformity within replication. Six anti-caking agents (Table 1) (Mississippi Blending Co., Inc., Keokuk, IA) were added at 2% (w/w) to shredded cheese and tumbled for 5 min in a fabricated tumbler to ensure complete coverage. Treated cheese was packaged (approximately 400g per bag) under modified atmospheres to contain a mixture of 75% CO_2 and 25% N_2 (Eliot et al., 1998) using a proportional gas blender (Smith Equip, Model 299-037F, Watertown, SD) and vacuum packager (Koch, Model X-200, Kansas City, MO). Oxygen and carbon dioxide levels were verified using a Model 6600 Headspace Oxygen/ Carbon Dioxide Analyzer (Illinois Instruments, Inc., Ingleside, IL). After packaging, all samples were stored at 4°C in a walk-in refrigerator (W. H. Porter, Inc., Model 1200, Holland, MI). Cheese samples were aged for a total of 25± 4 days before analyses were completed.

Table 1. Composition of anti-caking agents containing powdered cellulose, unmodified potato starch and anhydrous dextrose applied at 2% (w/w) to shredded low moisture part skim Mozzarella cheese treatments

Treatment	% Anti-caking Agent			
	No Treatment	Cellulose	Potato Starch	Dextrose
Control	100			
Cellulose		100		
Cellulose/ Dextrose		80		20
Potato			100	
Potato/ Dextrose			80	20
Blend A[1]		12	68	20
Blend B		12	88	

[1] Blends A and B are propriety blends developed by Allied Starch and Chemical, Keokuk, IA

Proximate Analysis of Cheese

Fat, moisture, protein, pH, chloride, calcium, and phosphorus were analyzed for each shipment of cheese received. Each analysis was completed in triplicate. Fat was determined using the Babcock test for cheese (van Slyke and Price, 1979). Moisture content was obtained using the force draft oven method described by AOAC Official Method 926.08 (AOAC, 1998). pH determinations were completed using the quinhydrone electrode method (van Slyke and Price, 1979). Chloride amounts as a quantification of salt were determined using Hach® Quantab® titrators for chloride as described by the AOAC Official Method 971.19 (AOAC, 1998). Water activity of cheese coated with anti-caking agents was measured at day 0, 1, and 7 using an Aqua Lab CX-2 (Decagon Devices, Inc., Pullman, WA). Protein and extent of proteolysis was measured by determining total nitrogen content in the cheese, AOAC Official Method 991.20 for Kjeldahl (AOAC, 1998) using the Rapid Still II (Labconco Corporation, Kansas City MO) and by determining percentage of total nitrogen soluble in water using methods described by Kuchroo and Fox (1982). Calcium and phosphorus samples were prepared using the method described in Guo and Kindstedt (1995) then measured using an Inductively Coupled Plasma Atomic Emission Spectrometer (Spectro Analytical Instruments, Inc., Fitchburg, MA).

Meltability Determination

In order to accurately assess the melt characteristics of the LMPS cheese, a University of Wisconsin (UW) meltmeter was constructed to analyze the cheese samples coated with the above described anti-caking agents as compared to an untreated sample (control). This modified squeeze flow apparatus is detailed in Muthukumarappan et al. (1999) and pictured in Figure 1. Samples of a specific size (30mm in diameter and 7mm in thickness) were created by placing treated shredded cheese samples into a fabricated template of the required size. Molded samples (4°C) were then heated at a specified temperature (72°C) in a constant temperature cabinet, model OV-490A-2 (Blue M Electric Company, Blue Island, IL) and measured for change in height under constant pressure. Constant pressure was achieved by utilizing a linear variable differential transformer (LVDT), DC-SE 500 (Shaevitz® Sensors, Hampton, VA) attached to an aluminum circular plate with diameter of 73mm. The weight of the disk attached to the end of the LVDT created a constant force of 0.7 N. Information was recorded every second for 10min using a Hydra 2635A data logger (Fluke Corporation, Everett, WA) and a personal computer. Meltability curves were created using six points determined by finding the difference after one second at time 0, 100, 200, 300, 400, and 500s. Results utilizing this method have been found to correlate well with biaxial elongational viscosity measurements (Kuo et al., 2000).

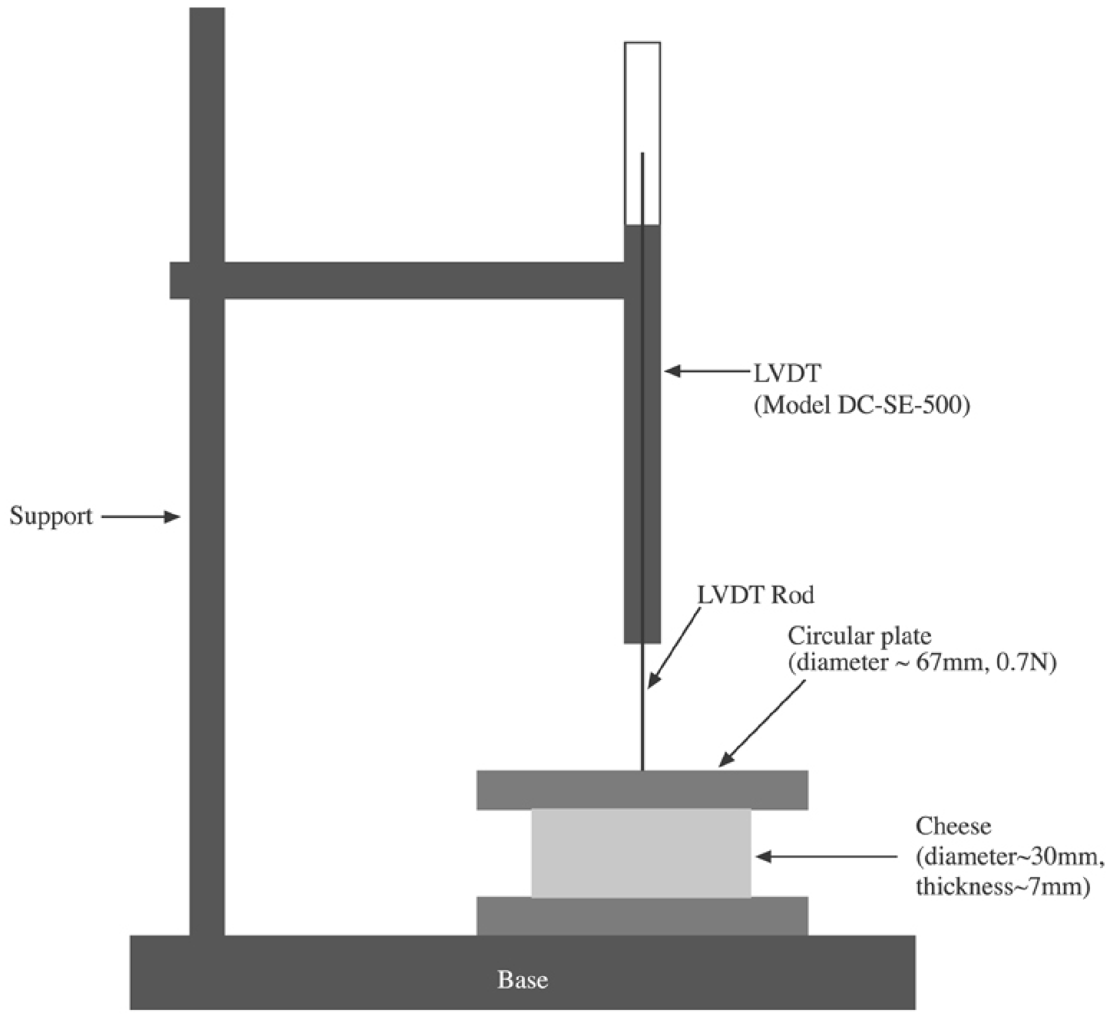

Figure 1. Modified squeeze flow apparatus (UW meltmeter) consisting of a linear variable differential transformer (LVDT) with attached aluminum circular plate constructed at Virginia Tech. Figure adapted from Muthukumarappan et al., 1999.

Stretchability Determination

Stretchability measurements were obtained using a modified procedure for helical viscometry as described by Kindstedt and Kiely (1992). An Instron Universal Testing Instrument (UTI) (Model 1011, Canton, MA) was outfitted with a Brookfield viscometer, model DV-I, 5X HBDV-1+ (Brookfield Engineering Laboratories, Inc., Middleboro, MA) with attached T-bar spindle, type E, in order to measure apparent viscosity of the melted cheese sample (Figure 2). The Instron was set to travel at 22 mm/ min while the viscometer rotated at 1.0 rpm. Samples containing 150 g of shredded LMPS cheese were placed in graduated cylinders measuring 58mm in internal diameter and 257 mm in height then covered with parafilm. The cheese was melted in a 60°C waterbath for 30 minutes before 25 ml of butteroil was added to the surface to prevent moisture loss. The samples were tempered for an additional 30 minutes at 60°C with the probe located equidistant from the bottom and sides of the graduated cylinder. The viscometer and UTI were activated simultaneously and data were recorded by reading the apparent viscosity (centipoise (cP)) every five seconds until the UTI traveled a total distance of 130 mm. Stretchability curves were created using the data obtained and analyzed by comparing six points (0, 20, 40, 60, 80, 100 s) along the curves.

Figure 2. Apparatus for measuring apparent viscosity of melted Mozzarella cheese. A Brookfield Viscometer with t-bar spindle has been attached to an Instron Universal Testing Instrument.

Free Oil Formation Determination

Free Oil (FO) formation was measured using a modified Babcock procedure developed by Kindstedt and Rippe (1990). Eighteen gram shredded LMPS cheese samples were weighed into 50% Paley-Babcock cheese bottles. The prepared bottles were placed in a boiling waterbath for four min to melt the samples. Immediately after removal, 20 ml of distilled water (57.5°C) was added to each and the samples were centrifuged (836rpm) at 57.5°C for 10 min. A 1:1 mixture of methanol and distilled water was added to attain a final volume in the calibrated portion of the neck. Samples were centrifuged for two min then rocked gently for 10 s to dislodge any trapped oil droplets. The bottles were centrifuged again for two min, rocked for 10 s, and centrifuged for a final two min. The bottles were tempered in 57.5°C waterbath for five min before glymol was added to facilitate reading of the calibrated neck. FO was reported as a percentage in cheese and also as a percentage in total cheese fat, free oil on fat basis (FOFB). FO was measured by dividing the measured fat column by two and recording the results. FOFB was calculated by using the results from FO and then dividing by the total fat found in the cheese sample.

Analysis of Data

The statistical consulting center at Virginia Tech provided guidance for experimental design aspects of the project and for final analysis of the collected data. A randomized complete block design was implemented for data collection. Analyses were performed in triplicate on three different blocks of cheese. The data were analyzed using one-way ANOVA in JMP® version 4.0.4 (SAS, Cary, NC) with mean comparisons made using Tukey-Kramer HSD when significant differences ($p<0.05$) were observed.

RESULTS AND DISCUSSION

Proximate Analysis

Fat percentage, moisture, salt content, as well as pH were analyzed to ensure uniformity of cheese sampling (Table 2). All analyses performed concurred with previously published values (Kindstedt, 1993b). Chloride content of the cheese samples did vary significantly between the three treatments which is evident by the large standard deviation. However, differences found did not significantly impact the measured functional properties of melt, stretch, and free oil.

All cheese samples were aged for 25±4 days in order to achieve the desired level of proteolysis required to attain the proper level of functionality necessary for industry uses of Mozzarella cheese (Kindstedt, 1993a). Cheese samples were analyzed for protein content, water soluble nitrogen (WSN) content, and calcium and phosphorus levels (Table 3). WSN is an indicator of the level of proteolysis which has occurred within the cheese (Kuchroo and Fox, 1982). The amount of nitrogen released indicates the degradation of protein aggregates within the cheese matrix. Nitrogen moves from protein fibers into serum channels where it can be extracted using water, homogenization, and centrifugation (Kuchroo and Fox, 1982). Calcium and phosphorus levels also provide a good indication of proteolysis. Solubilization of calcium phosphate found in micelles occurs as pH decreases during cheese making (van Hooydonk et al., 1986). During aging, this increase in soluble calcium as compared to colloidal calcium will increase plasticization of the cheese thereby increasing the functional properties of melt and stretch (Guinee et al., 2000).

Table 2. Mean values[1] for the initial composition of shredded low moisture part skim Mozzarella cheese

	$\bar{x}$	±SD	±SEM
Fat %[2]	20.83	0.5	0.167
Total Solids %[3]	51.17	0.37	0.124
Chloride %[4]	1.88	0.25	0.083
pH[5]	5.33	0.04	0.014

[1] n=9
[2] Babcock test for cheese
[3] Forced draft oven method
[4] Quantab titrators for chloride
[5] Quinhydrone electrode method

Table 3. Mean values[1] for protein and proteolysis determination of shredded low moisture part skim Mozzarella cheese aged 24 ± 5 days

	$\bar{x}$	±SD	±SEM
Protein[2]	25.16	0.70	0.235
WSN[3]	29.26	2.69	0.898
Ca[4]	656.7	52.96	17.65
P	454.0	36.48	12.16

[1] n=9
[2] Macro-Kjeldahl method
[3] Water Soluble Nitrogen determined by methods described in Kuchroo and Fox, 1982
[4] Ca and P levels measured using an Inductively Coupled Plasma Atomic Emission Spectrometer

Water Activity

Water activity measures the ratio between water vapor pressure exerted by a food and the water vapor pressure of pure water at the same temperature. Pressure exerted by water vapor in the food determines the sorption of water vapor into or out of a food system (Fox and McSweeney, 1998). Interactions between the applied anti-caking agents and the shredded cheese surface were evaluated with this procedure. All results were compared to an untreated control cheese. Water activity measured at day 0, 1, and 7 (after treatment with anti-caking agents) did result in some significant differences (Table 4). Cheese coated with a blend of 80% cellulose/ 20% dextrose was identified as having a lower water activity when compared to cheese coated with blends containing 100% cellulose, 100% potato starch, and 88% potato starch/ 12% cellulose after day one. The result obtained during testing for 80% cellulose/ 20% dextrose for day one is suspect due to the low value (.958) recorded after a higher value was found for day zero (.962). By day seven, the control cheese (no applied anti-caking agent) was found to be significantly different from cheese coated with 100% cellulose, 80% cellulose/ 20% dextrose, 100% potato starch, and 88% potato starch/ 12% cellulose. The control cheese exhibited the largest increase in activity from day one to seven.

The addition of an anti-caking agent seems to have a barrier effect on the ability of treated shredded cheese samples to increase in water activity. The control cheese was able to absorb more water vapor from the environment than samples treated with anti-caking agents. Available water is essential in order to obtain an acceptable level of protein hydration in the cheese (McMahon and Oberg, 1998). Protein hydration is paramount to the formation of acceptable levels of melt and stretch in Mozzarella cheese. Yun et al. (1993) reported the effects of increased moisture content on proteolysis. Greater amounts of moisture in cheese contribute to higher degrees of proteolysis. Water absorption can also contribute to an increase in Maillard browning reactions during cheese baking when residual sugars are available (Fox and McSweeney, 1998).

Table 4. Water activity values[1] during 4°C storage of low moisture part skim Mozzarella cheese treated with various anti-caking agents

Anti-caking Agent	Day 0	Day 1	Day 7
Control[2]	.960	.961[ab]	.973[a]
100% cellulose[3]	.961	.965[a]	.964[b]
80% cellulose/ 20% dextrose[4]	.962	.958[b]	.964[b]
100% potato starch[5]	.960	.964[a]	.965[b]
80% potato/ 20% dextrose[6]	.963	.962[ab]	.966[ab]
Blend A[7]	.964	.962[ab]	.967[ab]
Blend B[8]	.965	.964[a]	.964[b]
SE	0.002	0.001	0.002

[1] n=9
[2] Control – no anti-caking agent
[3] Cellulose – powdered cellulose
[4] Dextrose – anhydrous dextrose
[5] Potato starch – unmodified potato starch
[6] Potato/ dextrose – 80% unmodified potato starch and 20% dextrose
[7] Blend A – 68% potato starch/ 20% dextrose/ 12% cellulose
[8] Blend B– 88% potato starch/ 12% cellulose
[abc] means with different superscripts in columns are significantly different at $p<0.05$

Meltability

Meltability assessment of shredded cheese treated with various anti-caking agents was performed. Rudan et al. (1998) explain that when cheese begins to melt, fat globules expand outside the confines of the protein matrix, thereby coating the exterior of the shred. As the temperature increases, apparent viscosity decreases due to reductions in protein-protein interactions. Once this occurs, the shreds begin to collapse and flow due to the forces of gravity. Differences in height (mm) after one second were recorded for 1, 100, 200, 300, 400, and 500 s (Appendix Table 1). No significant differences ($p>0.05$) were observed between the treated samples and the control cheese for any of the time intervals. All treated samples reacted slowly to the initial force (smaller amount of melt difference) but increased rapidly at the 100s observation. The control however, had an immediate change in height difference followed by a more gradual degree of melt throughout the remainder of the experiment. Due to a lack of surface coating by anti-caking agent in the control samples, speculation leads to the conclusion that the cheese temperature rose more quickly in the control than treated cheese samples. Control samples reached their softening point at a faster rate indicating a higher degree of meltability after one second. This could have been caused in part by decreased protein interactions caused by increased water activity in the control cheese compared to all coated samples tested during heating.

Figure 3 demonstrates that measurements observed for all treated samples at the second time interval (100s) increased in meltability compared to the initial values observed in the control cheese. Formulations containing dextrose and 100% cellulose produced the greatest decrease in height in this time frame. At 200s, a decrease in height similar to the initial decrease for all values except the uncoated control samples was observed. By 300s, all mean values for difference in height observed were nearly equivalent to each other.

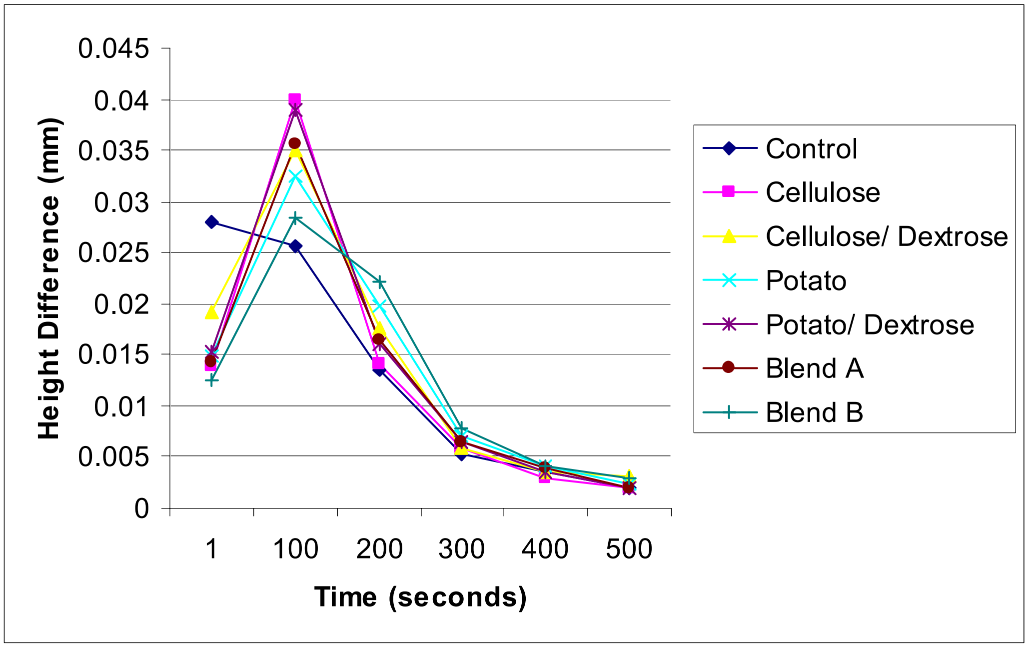

Figure 3. Meltability curves for seven treatments of low moisture part skim Mozzarella cheese. (significance at $p<0.05$).

The melt curve (Figure 3) exhibited by the control Mozzarella corresponds with published results (Muthukumarappan et al., 1999). The control sample showed a steady decline in overall height difference over time. As stated before, when fat globules expand during initial heating, FO is released from the protein-lipid matrix and migrates to the shred surface. The capacity for the anti-caking agents to absorb moisture (and FO as exhibited later) may have delayed the collapse of the protein matrix, thereby reducing the initial amount of melt. As the temperature of the cheese increased and more FO was released, fewer and fewer protein interactions remained. This prevented the anti-caking agents from continuing as a protective barrier which allowed for minimum stress requirements to be met and the shreds were able to flow. The build up of FO, when finally released, resulted in the increase in melt of the treated samples after 100s. More research is needed to determine the exact cause of the increased meltability of coated cheese samples.

Stretchability

Stretchability of melted Mozzarella cheese was quantified by determining the apparent viscosity of the sample cheeses. Apparent viscosity measurements help to determine the expected "chewiness" of the cheese product. No significant differences were observed between any of the treatments for the first five data points recorded (time 0, 20, 40, 60, and 80s) ($p>0.05$) (Appendix Table 2). Significant differences were noted at 100s between the control cheese and cellulose.

Control samples had the highest apparent viscosity while cellulose results indicated the lowest viscosity measurement of all treatments at 100s. Figure 4 demonstrates apparent viscosity measurements for each of the treatments over time. Slightly higher apparent viscosity numbers were observed for the control sample for each of the time points while the remaining treatments all performed similarly. The lack of competing ingredients on the cheese shreds may have allowed for slightly higher levels of protein-protein interactions during heating which in turn created a more viscous melted cheese sample. Kuo et al. (2000) found that cheeses held at 60°C for a significant amount of time (20 min) underwent casein aggregation. Additionally, samples containing dextrose (80%

cellulose/ 20% dextrose, 80% potato starch/ 20% dextrose, and 68% potato starch/ 20% dextrose/ 12% cellulose) all produced slightly lower apparent viscosity measurements.

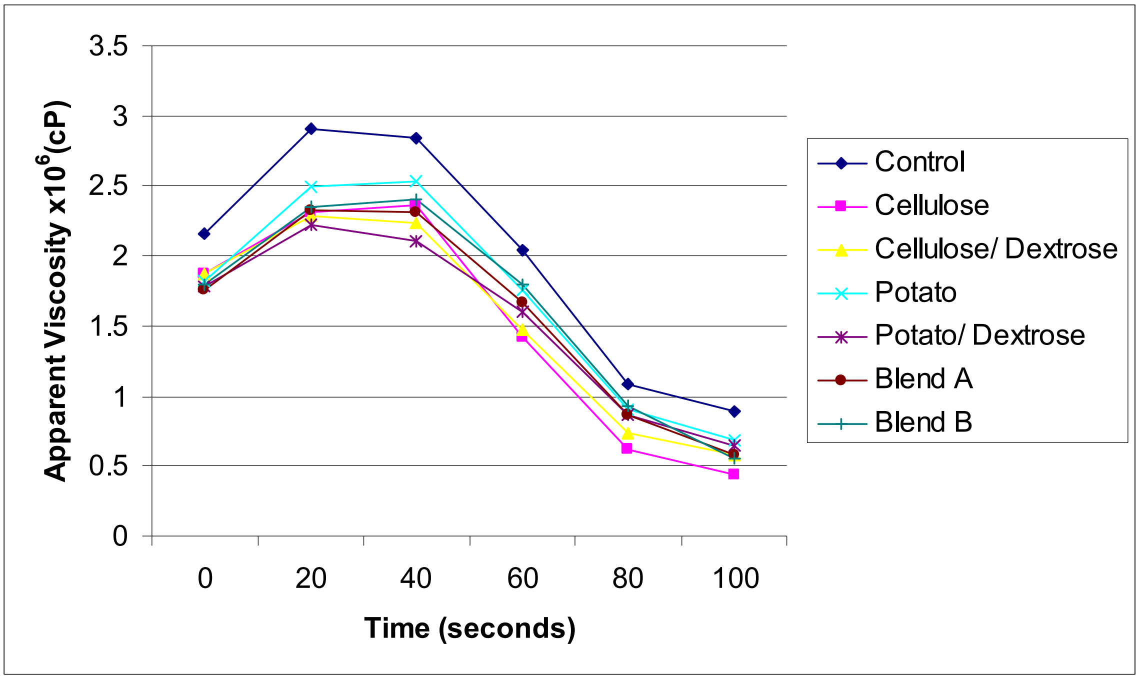

Figure 4. Apparent viscosity measurements for determining stretchability of low moisture part skim Mozzarella cheese treated with various anti-caking agents (2% w/w). Significant differences ($p<0.05$) were found between cellulose and control treatments at 100s.

Protein-protein interactions play the largest role in determining cheese stretch. The ability of casein interactions to easily break and reform provides the characteristic behavior of Mozzarella cheese (Johnson, 2000). An increase in protein-protein interactions would result in an increased apparent viscosity.

Additional research focusing on sensory attributes would be beneficial in determining if chewiness of baked cheese was evident using different anti-caking agents. Metzger and Barbano (1999) detail a comparison between an empirical method and a traditional sensory method for quantifying this quality characteristic. Similar results were obtained in both techniques for determining postmelt chewiness.

Free Oil Formation

FO formation was calculated by determining the percentage of free oil in the cheese and percentage of total cheese fat (FO on a Fat Basis – FOFB). Statistically significant differences were discovered between treatments ($p<0.05$) (Table 7). The treatment containing 80% cellulose/ 20% dextrose was found to have the highest mean FO % of all treatments (6.03%), just ahead of the control cheese samples (5.78%). Tukey's HSD for mean comparison showed that the control treatment contained significantly higher levels of FO than 100% potato starch, 68% potato starch/ 20% dextrose/ 12% cellulose, and 88% potato starch/ 12% cellulose treatments under laboratory conditions. Cellulose (100%) treated cheese was not found to be statistically different from control samples. The potato starch and cellulose blend (Blend B) contained the lowest mean FO% of all treatments studied. This formulation resulted in an almost 30% decrease in the amount of FO as compared to the control. Potato starch (100%) exhibited a 20% reduction in the amount of FO produced in the melted cheese samples over untreated cheese samples. Preliminary sensory data (not reported) indicated that a difference between treated samples and control cheeses could be seen visually, but differences noted may not have been based solely on the appearance of FO.

The appearance of excess FO on the surface of melted Mozzarella cheese is an undesirable characteristic when found on the surface of pizza and other heated food products. While a certain degree of FO formation is important for melt characteristics, excess production increases the perception of higher fat content by consumers. The incorporation of potato starch as an additional ingredient in anti-caking agent formulations reduces the appearance of FO without losing desired functionality in meltability and stretch characteristics. Additional sensory analysis of acceptability levels of FO formation on the surface of Mozzarella cheese would be beneficial in determining which formulation of anti-caking performed most effectively.

Table 5. Mean values[1] for Free Oil (FO) formation of melted shredded low moisture part skim Mozzarella cheese treated with various anti-caking agents (2% w/w)

Anti-caking agent	FO %[2]
Control[3]	5.78[ab]
100% cellulose[4]	5.44[abc]
80% cellulose/ 20% dextrose[5]	6.03[a]
100% potato[6]	4.58[c]
80% potato/ 20% dextrose	5.03[bc]
Blend A[7]	4.50[c]
Blend B[8]	4.17[c]
SE	0.205

[1] n=9
[2] measured column divided by 2
[3] Control – no anti-caking agent
[4] Cellulose – powdered cellulose
[5] Dextrose – anhydrous dextrose
[6] Potato – unmodified potato starch
[7] Blend A – 68% potato starch/ 20% dextrose/ 12% cellulose
[8] Blend B – 88% potato starch/ 12% cellulose
[abc] columns of means with different superscripts are significantly different ($p<0.05$)

CONCLUSIONS

Functional characteristics of melted Mozzarella cheese were affected by the addition of various anti-caking agent treatments. Water activity of control samples was significantly higher than those treated with anti-caking agents after seven days of equilibration. Meltability and stretchability characteristics were not altered compared to an untreated control. FO formation was found to be significantly less in those treatments containing potato starch. Treatment containing 88% potato starch and 12% cellulose (Blend B) produced the least amount of FO.

The use of potato starch alone and in conjunction with powdered cellulose for use in anti-caking agents has been shown to be more effective for free oil control and could be considered an effective alternative for traditionally used cellulose-based anti-caking agents. The additional improvement of reduced FO formation makes the use of potato starch even more appealing to the pizza industry. Further sensory evaluation of the benefits of potato starches should be performed to adequately assess the true consumer opinion of the functionality of the treated cheeses.

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APPENDIX

Table 1. Means[1] for meltability (mm) of shredded low moisture part skim Mozzarella cheese treated with various anti-caking agents.

Anti-caking agent	Height difference (mm)[8]					
	0sec	100sec	200sec	300sec	400sec	500sec
Control[2]	0.028	0.026	0.014	0.005	0.003	0.002
100% cellulose[3]	0.014	0.040	0.014	0.006	0.003	0.002
80% cellulose/ 20% dextrose[4]	0.019	0.035	0.018	0.006	0.004	0.003
100% potato[5]	0.015	0.033	0.020	0.007	0.004	0.002
80% potato/ 20% dextrose	0.015	0.039	0.016	0.006	0.003	0.002
Blend A[6]	0.014	0.036	0.016	0.006	0.004	0.002
Blend B[7]	0.012	0.028	0.022	0.008	0.004	0.003
SE	0.005	0.004	0.002	0.0009	0.0005	0.0003

[1] n=9
[2] Control – no anti-caking agent
[3] Cellulose – powdered cellulose
[4] Dextrose – anhydrous dextrose
[5] Potato – unmodified potato starch
[6] Blend A – 68% potato starch/ 20% dextrose/ 12% cellulose
[7] Blend B – 88% potato starch/ 12% cellulose
[8] UW Meltmeter with a constant force of 0.7N; cabinet temperature of 72°C
[9] No significant differences (p>0.05) were found

Table 2. Mean values[1] for determination of stretchability of melted shredded low moisture part skim Mozzarella cheese treated with various anti-caking agents

Anti-caking agent	Apparent Viscosity (cP) (10^6)					
	0sec	20sec	40sec	60sec	80sec	100sec
Control[2]	2.16	2.91	2.84	2.04	1.09	0.89^{a}
100% cellulose[3]	1.87	2.31	2.36	1.42	0.62	0.44^{b}
80% cellulose/ 20% dextrose[4]	1.87	2.29	2.24	1.47	0.73	0.58^{ab}
100% potato[5]	1.82	2.49	2.53	1.76	0.91	0.69^{ab}
80% potato/ 20% dextrose	1.78	2.22	2.11	1.60	0.87	0.64^{ab}
Blend A[6]	1.76	2.33	2.31	1.67	0.87	0.58^{ab}
Blend B[7]	1.80	2.356	2.40	1.80	0.93	0.56^{ab}
SE	0.14	0.25	0.31	0.28	0.13	0.08

[1]n=9

[2] Control – no anti-caking agent

[3] Cellulose – powdered cellulose

[4] Dextrose – anhydrous dextrose

[5] Potato – unmodified potato starch

[6] Blend A – 68% potato starch/ 20% dextrose/ 12% cellulose

[7] Blend B – 88% potato starch/ 12% cellulose

[ab] means with different superscripts within a column are significantly different ($p<0.05$)

VITAE

Maureen Akins is a native of Virginia and obtained her B.S. degree in Biology in 1998 from Virginia Polytechnic Institute and State University. She has been happily married to a Virginia Tech alumnus, Grant Akins since 1998. She received her M.S. in Food Science and Technology from Virginia Polytechnic Institute and State University in December 2002.