Journal of Textiles, Coloration and Polymer Science
https://jtcps.journals.ekb.eg/

Egyptian Society for Textile Science and Technology
الجمعية المصرية لعلوم وتكنولوجيا النسيج

Significance of Casein and its applications in the manufacture and finishing of various textiles

Heba Ghazal * and Abdallah N. El-Wekil
Textile Printing, Dyeing and Finishing Department, Faculty of Applied Arts, Benha University, Benha, Egypt

Abstract

Casein is a kind of biomolecular condensate that is produced by mammary cells and found in milk as colloidal casein micelles. When eaten as food, casein supplies amino acids, carbohydrates, and the essential minerals calcium and phosphorus, which is widely employed in the textile sector for a number of applications such: Printing, Finishing, Sizing, Adhesive, Dyeing and Casein Fiber. in This chapter provides a brief and comprehensive o verview of the casein's manufacturing and applications in textile as well as finishing processing such Antimicrobial, Flame-retardant, The durability, physiological comfort and UV protection. Casein is a flexible protein kind of biomolecular condensate that is produced by mammary cells contains a high concentration of proline amino acids, which inhibit proteins from generating secondary structural motifs. All things considered; casein is a substance with a wide range of uses in the textile sector.

Keywords: Milk, Fiber, Antimicrobial Flame-retardant , The durability, UV protection

Introduction

Casein (from Latin *caseus* "cheese") is a family of related phosphoproteins (αS1, aS2, β, κ) that are commonly found in mammalian milk, comprising about 80% of the proteins in cow's milk and between 20% and 60% of the proteins in human milk.[1] Sheep and cow milk have a higher casein content than other types of milk with human milk having a particularly low casein content.

Casein is the primary emulsifier in milk, that is, it helps in mixing oils, fats, and water in milk.[2]

Casein is a flexible protein that may be included in food or utilised as a main component of cheese. The most common form of casein, sodium caseinate, is an excellent emulsifier. Casein is a kind of biomolecular condensate that is produced by mammary cells and found in milk as colloidal casein micelles. When eaten as food, casein supplies amino acids, carbohydrates, and the essential minerals calcium and phosphorus.

Casein contains a high concentration of proline amino acids, which inhibit proteins from generating secondary structural motifs. Furthermore, there are no disulfide bridges. As such, it has relatively little tertiary structure. Its high hydrophobicity makes it poorly soluble in water. [3]

Casein micelles are a suspension of particles found in milk that resemble surfactant-type micelles just somewhat in that they are spherical and have hydrophilic portions that are at the surface. Nonetheless, the core of a casein micelle is very hydrated, in stark contrast to surfactant micelles. Hydrophobic interactions and calcium ions hold the caseins in the micelles together. A variety of chemical hypotheses might explain casein's unique conformation in Casein contains a high concentration of proline amino acids, which inhibit proteins from generating secondary structural motifs. Furthermore, there are no disulfide bridges. As such, it has relatively little tertiary structure. Its high hydrophobicity makes it poorly soluble in water.

Casein micelles are a suspension of particles found in milk that resemble surfactant-type micelles just somewhat in that they are spherical and have hydrophilic portions that are at the surface. Nonetheless, the core of a casein micelle is very hydrated, in stark contrast to surfactant micelles. Hydrophobic interactions and calcium ions hold the caseins in the micelles together. A variety of chemical hypotheses might explain casein's unique conformation in the micelles. [4] According to one of them, the micellar nucleus is made up of many submicelles, with κ-casein microvillosities making up the perimeter. According to a different concept, casein-interlinked fibrils create the nucleus. [5] Lastly, a twofold connection between the caseins is suggested by the most current model in order for gelling to occur.

*Corresponding author: Corresponding author: heba_ghazal@yahoo.com, Tel. 00201065302883
Receive Date: 07 June 2024, **Revise Date:** 23 June 2024, **Accept Date:** 24 June 2024
DOI: 10.21608/jtcps.2024.296055.1379

Micelles are viewed by all three models as colloidal particles made of soluble κ-casein molecules encased in casein aggregates.

Casein has an isoelectric point of 4.6. Casein has a negative charge in milk because the pH of milk is 6.6. The refined protein has no solubility in water. It is easily dispersible in diluted alkalis and salt solutions such aqueous sodium oxalate and sodium acetate, despite the fact that it is likewise insoluble in neutral salt solutions.

The enzyme trypsin can hydrolyze a phosphate-containing peptone. It is used to form a type of organic adhesive. [6]

- Milk contains a protein called casein, which is widely employed in the textile industry for a number of applications. The following are a few uses for casein in the textile sector:
- **Printing**: Textile printing inks can be bonded with casein. It works really well as an adhesive and may be applied to cloth to attach pigment particles.
- **Finishing**: Fabrics can be finished using casein as a finishing agent. It facilitates handling and provides the cloth a smooth, soft touch.
- **Sizing**: The textile industry uses casein as a sizing agent. Applying a protective layer to the yarn's surface in order to increase its strength and durability is known as sizing.
- **Adhesive**: The textile sector also uses casein as an adhesive. It may be used to attach fabric to other materials like paper, cardboard, or wood, as well as to join two textiles together.
- **Dyeing**: In the dyeing process, casein may be utilised as a mordant. A mordant is a chemical that improves the colour fastness of the dye and helps it stick to the fabric.
- **Casein Fiber:** Casein, which is extracted from milk after the butterfat is removed, and a chemical are used to create milk fibres, which are regenerated protein fibres.

All things considered, casein is a substance with a wide range of uses in the textile sector. Because of its inherent qualities, it is a desirable substitute for synthetic materials and a sustainable choice for producers of textiles. In this review we talk about casein and its application in textile.

The manufacturing

One of three methods is typically used to make casein from skim milk (buttermilk is rarely used). For naturally soured casein, warm skim milk is set with rennet extract until the calcium paracaseinate clots. Once enough lactic acid develops from the fermentation of milk sugar by the ever-present bacterium Streptococcus lactisi, the casein is precipitated; for rennet casein, the clot is cut into small pieces to allow the whey to drain. The curd is removed from the whey using all three techniques, and then it is cleaned with water, drained or pressed, dried on the ground or heated air, and packed for sale. A large portion of the calcium phosphate in the milk is retained by rennet casein.

Casein structure

Proteins, along with lipids and carbohydrates, which are also necessary for life, are arguably the most significant class of biological compounds. One protein that may be found in milk called casein is employed as a binding agent on its own in a variety of meals. Its composition consists of the presence of amino acids. Amino acids contain a range of groups that are reactive to chemicals, such as peptide bonds and phenolic hydroxy groups. Amino groups, ketones, and hydrazine groups are also present in casein. Figure shows its structure. 1

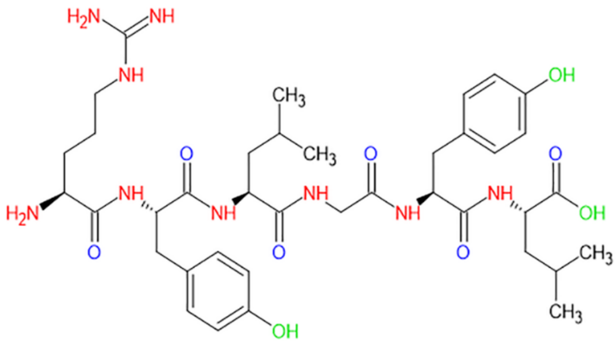

Figure 1: Structure of casein [7]

Extraction of casein from milk

The casein separates from the sample and leaves behind a clear solution when non-fat milk is heated and then precipitated with acetic acid. When acid is added to the solution and stirred, the casein separates into an amorphous material that may be filtered out with a suction filter. Precipitates are created in the milk sample when acetic acid is introduced. After decanting the filtrate and rubbing it with a suitable amount of 0.1% sodium hydroxide solution, the precipitates are then rinsed two or three times with water. The resultant solution is then filtered through a cloth. After that, casein-containing precipitates are treated in a beaker with 100% alcohol.After allowing the ether to settle for a few minutes, the separated casein is combined with the ether solution once more, and the procedure is repeated with a second batch of ether. Filter the product one more after the second ether wash. Any trace amounts of fat that could have precipitated with the casein are eliminated by the ether washings. [8].

Casein Fiber

Casein, which is extracted from milk after the butterfat is removed, and a chemical are used to create milk fibres, which are regenerated protein fibres. The viscose technique used to make viscose rayon is also utilised to make casein fibres. Three pounds of milk fibre are produced from 100 pounds of skim milk. The protein casein and the chemical acrylonitrile—which is used to manufacture acrylic—combine to form milk fibre. It's created by a method like to that of rayon or viscose, but since it reacts like wool because it's a regenerated protein fibre rather than a regenerated cellulose fibre. According to Kiplinger, this indicates that it colours like wool and even has a woolly fragrance when burned.

Characteristics of Milk Fiber

The humectant factor, a naturally occurring protein found in milk fibre, produces smooth, sensitive skin.

- Its hygroscopic nature allows it to absorb moisture extremely well.
- Because the fibre contains amino acids, it has antibacterial and antifungal properties.
- It has the same lustrous, plush look, texture, and comfort as silk.
- Dyeing it is a relatively simple process that may be done at room temperature.
- It blends nicely with a variety of other fibres, including cotton, modal, bamboo, and tencel. [9]

Properties of Milk Fiber

The fibre has a smooth, white surface and subtle striations by nature. Due to pitting, the cross section has a mottled, bean-shaped to spherical form. It may be twisted into very thin filaments with a diameter of 20–30μ.

Physical and chemical properties of casein fiber

- Tenacity, dry: 9.7–8.0 cN/tex (1.1–0.9 g/den)
- Elongation: 60–70%
- Specific gravity: 1.3
- Effect of heat: Turns yellow if heated at 100°C itself for long time, at 150°C it decomposes.
- Moisture regain: 14%
- Very minimal effect from sunshine, similar to wool.
- Acid impact: Minimal acid has no impact. Strong mineral acid that breaks down.
- Alkali's effect: vulnerable to alkali. Disodium hydrogen phosphate and sodium bicarbonate don't really do anything. Strong alkali breaks down.
- Organic solvents: Equivalent to solvents used in dry cleaning. [10]

Benefits of Milk Protein Fiber

Modern milk fibre is stronger, more superior than fibres manufactured by humans, and less harmful to the environment. Here are a few advantages of consuming casein fibre:

- Because it uses the continuous graft polymerization process, it is completely environmentally benign.
- Since the product contains no formaldehyde, it qualifies as a "Green Product."
- Milk casein, not fresh milk, is used to make milk protein fibre. Acid, reactive, or cationic dyes are possible options for this type of specialty fibre.
- The pH of casein fibre is 6.8, the same as the skin's pH. As a result, products composed of them are more skin-friendly.
- Milk fibre has a natural antibacterial rate of more than 80% and comprises seventeen amino acids. Thus, casein fibre has a hygienic purpose.
- Made using a highly sophisticated method, it is a novel synthetic fibre with milk protein as its primary ingredient. The benefits of both natural and synthetic fibres are blended in casein fibre.
- These have superior air permeability, better comfort, and superior water transportation.

Its limited durability, ease of wrinkling after washing, and lack of suitability for machine cleaning are some of its drawbacks. Milk cloth never truly took off since there were so many alternative materials available, including polyester. [11]

Functions for Milk or Casein Fibre:

Milk fibre is said to be the ideal material for making knickers because of its bacteriostatic and healthful properties. As was previously mentioned, milk casein proteins are thought to be the primary component of milk protein fibre, which has lubricating properties for the skin. The natural humectant element found in milk protein helps to smooth, minimise wrinkles, and maintain skin hydration, all of which may help people realise the benefits of taking milk baths. Originally, felt for hats was made from milk fibre. Knitted berets are made from combinations of wool and casein. Blended fabrics such as nylon or casein/cotton are used to make jumpers, cardigans, T-shirts, and interlock outerwear. The following lists common applications for milk protein fibre. [12]

Dyeing of Casein Fibers with Natural Dye Sources after Ozonation

Casein fibres are typically clean, and in terms of pretreatment, bleaching alone may enough for finishing. In this investigation, ozone gas from an ozone generator (ProdOzon) was utilised to bleach the materials. The generator's capacity was 25 grammes per hour, and the O_3/O_2 gas flow rate was set at 5 L per minute. In this phase of the research, ozonated materials were coloured with onion skin, a natural dye source. It was discovered that this natural dye source may produce dark brownish orange (brick colour) colours as well as brilliant colours when dyeing casein fibres. Ozonation resulted in colour alterations, but also caused shade shifts. The colored samples were also tested for rubbing, washing, and light fastness. Our goal was to examine the processing of casein-based textiles using eco-friendly finishing methods. To promote eco-friendliness, ozone gas was explored as a pretreatment option, followed by natural colouring. Coloration was achieved using onion skin. In addition to their special advantages, we want to demonstrate an eco-friendly fabric finishing approach. Although ozone can improve the whiteness of casein fibres, the effect was limited.

The degree of whiteness enhancement varies with ozonation time and moisturising circumstances.

The ozonated and untreated textiles were coloured using onion skin, a natural dye source. Onion skin can be used to colour casein, resulting in enough fastness. Using onion skin to colour casein fibres allows for the reuse of a vegetable waste source. [13]

Electrospun casein/PEO nanofibrous yarn

Natural protein casein has been employed as a biopolymer-based fiber-producing resource. This fibre has a pH that is similar to human skin and offers excellent comfort. The purpose of this study was to determine if it would be feasible to generate casein nanofiber twisted yarn with the maximum protein content in hybrid yarn under the right spinning circumstances and with the desired end result. The desired yarn was made up of 10% polyethylene oxide and 90% casein. The yarn was reinforced utilising a variety of cross-linking techniques, and the most effective way was found for spinning an engineered yarn that was optimised. Thus, the optimised yarn (a combination of 90% casein and 10% polyethylene oxide) was subjected to a biodegrading test with 40% di-isocyanate added as a strengthener. After ten days, the sample degraded mostly in the solvent and its strength drastically decreased, allowing it to be classified as a biodegradable and environmentally friendly fibre. Important optimised conditions were found for the electrospinning parameters, such as input voltage, feeding rate, twist, distance between the two nozzles, distance between the neutral substrate and the collector, and distance between the centre of the electromagnetic shield and the neutral substrate. The nanofiber yarn that was in contact with PEO with a concentration of 26% and casein with a concentration of 10% had an inappropriate strength. Increasing the di-isocyanate crosslinking agent to 40 weight percent would greatly improve the nanofiber yarn's strength and work of rupture.

The nanofiber yarn tensile characteristics in terms of elongation at break are significantly affected by increasing the di-isocyanate component within the PEO/casein solution up to 20%, according to statistical analysis. Further increases in di-isocyanate content decrease yarn elongation, which may be attributed to the formation of many more network structures between the chemical constitutive components. The increasing rate of elastic modulus resulting from adding 20% di-isocyanate crosslinking agent into the PEO/casein solution is not statistically significant, but there are significant differences between the elastic modulus of strengthened and unreinforced PEO/casein yarns by increasing the amount of di-isocyanate component up to 40%.

When compared to unreinforced yarns, the nanofiber yarn strengthened with 40% di-isocyanate would show brittleness in the cross section morpological photographs. According to the results of the biodegradation test, samples exposed to the buffer solution would begin to lose strength after 10 days, and the nanofiber yarn would completely degrade after 18 days. [14]

Casein in textile Finishing

Casein modification for multipurpose cotton finishing

In the present study, a new green flame retardant substance was synthesised by modifying casein. Casein was modified using melamine and sodium pyrophosphate. Glyoxal was employed as a crosslinker. The modified casein was then applied to the cotton fabric using the exhaust technique, and the subsequent percentage add-on was calculated. The limiting oxygen index (LOI) value was also studied to determine flame retardancy performance, and it was discovered to have improved. Thermogravimetric analysis (TGA) shows that treated textiles outperform untreated cotton fabrics. The scanning electron microscopy (SEM) study reveals a very excellent deposition of modified casein on the treated cotton fabric surface. The treated cotton fabric's UV protection factor (UPF) increased significantly.

Thus, a novel green flame-retardant material created by modifying casein offers a multifunctional finish with increased capabilities.

Methods Modification of casein

Casein was modified by reacting it with melamine and sodium pyrophosphate in 5:1:8 ratios for 2 hours in a three neck flask while stirring continuously at 30°C. Glyoxal (double the quantity of protein) was utilised as a cross-linking agent, which was added drop by drop to the reaction mixture. The process was then extended for 4 hours at 80°C while pH 5 was maintained using 20% acetic acid. Furthermore, to achieve total dissolution, the pH of the reaction liquid was lowered to 8 by adding 10% sodium hydroxide. The reaction was then continued for 2 hours at 90°C. After the reaction was completed, a dark brown solution was formed, which was then dried in an oven at 80°C for 24 hours.

Impact of Casein Modification

Casein is modified to provide a bio-based eco-friendly substance with flame retardancy and UV protection qualities for the cellulosic textile substrate. After using casein-based synthesised FR, the flame retardancy assessed in terms of LOI improved significantly. The thermal stability of the cotton fabric was also improved, and in the vertical flammability test, treated samples demonstrated self-extinguishment with little char length and a shorter after flame duration. Better flame retardancy in casein-based flame retardants may be due to the presence of inherent phosphate groups, phosphate from pyrophosphate moieties, intrinsic nitrogen content, and extra nitrogen from melamine moieties. This nitrogen and phosphorus (NP) synergy appears to have had a significant impact in improving overall thermal stability. Although flame retardancy has no durability, it may have a useful application in areas such as hometech and protech where durability is not a top need. Furthermore, modified cotton textiles demonstrated exceptional ultraviolet protection due to the presence of hetero aromatic triazine and ring phenolic amino acids capable of quenching UV radiations. It is not only biodegradable and harmless, but also environmentally beneficial. One important constraint discovered is the hue of the cloth on finishing, which might be exploited creatively; nevertheless, more study is required to overcome this limitation. Therefore, the data clearly highlight the prospective potential For casein-based FR multifunctional cotton finishing, provided that durability and colouring difficulties are addressed.

The durability, physiological comfort, and flame resistance of cotton fabrics treated with casein

The hunt for environmentally benign flame retardants that provide fire performance equal to traditional flame-retardant chemicals has become more important [8,9]. In this regard, the efficiency of several biomacromolecules (whey proteins, caseins, hydrophobins, and deoxyribonucleic acid) were recently examined for textiles. [10].

Among these, the use of casein as a flame retardant might be an appealing alternative for increasing the value of the dairy business by using its byproduct/waste [11]. Casein is the most abundant milk protein (80%), acquired as a byproduct of skim milk manufacturing. Casein macromolecules can be thought of as poly amino acids with many phosphate groups in their micellar structure that disintegrate similarly to ammonium polyphosphate salt [12]. Because of its superior mechanical or barrier qualities, casein treatments are predicted to prevent, postpone, or partially block heat deterioration in a cellulosic fabric.

Furthermore, their moisture adsorption properties might partially disperse heat generated during cloth burning, diluting the created flammable volatile species [13]. In addition to environmentally responsible behaviour, flame retardant coatings are essential to ensure appropriate physiological comfort and mechanical qualities in textiles. This is significant since individuals exposed to fire threats are required to wear fire-resistant clothes for an extended period of time. In hot and humid settings, trapped moisture warms up; in cold ones, stored moisture causes a reduction in temperature and hypothermia [14]. The rise in temperature and increased body sweat can cause further pain, heat stress, and skin injury for the user [15].

As a result, fire resistant textiles require extra qualities such as air permeability, water vapour permeability, thermal conductivity, and surface roughness. The current study looks at how casein treatment affects the thermooxidative stability, flame retardant characteristics, and physiological comfort of cotton materials. Furthermore, the short-term durability of casein-treated cotton textiles was tested against water washing and UV radiation ageing. To the best of the authors' knowledge, this is the first study to look at the flame retardancy, physiological comfort, and durability of casein-treated cotton. As a result, this research might help avoid second-degree burn casualties caused by low intensity heat flux incidents.

The results of applied The casein protein on cotton textiles provides an environmentally beneficial flame retardant treatment while maintaining physiological comfort and mechanical characteristics. The casein treatment favoured cellulose dehydration by releasing phosphoric acid from its macromolecules. The thermogravimetric study indicated that the generation of thermally stable char increased with the presence of a local intumescent flame retarding mechanism. When the horizontal flame was applied, it had a protective impact on the underlying cotton fabric by restricting oxygen penetration, preventing the development of flammable volatile compounds, and absorbing the heat produced during burning. The samples treated with 30 w/v% casein suspension had the longest overall burning duration (+34%), however this came at the expense of physiological comfort and mechanical qualities. The image analysis approach was effectively employed to overcome the constraints of laboratory test assembly for evaluating tiny changes in flame propagation. In comparison to untreated cotton fabric, 15 w/v% casein concentration resulted in an estimated 50% smaller burn area and 43% lower burn time. Lower casein concentrations (less than 20 w/v%) were discovered to give appropriate flame retardant effectiveness while maintaining physiological comfort and mechanical qualities. Finally, the persistence of flame retardant characteristics against washing and ageing was determined to be insufficient for long-term use. However, future study might benefit from the combination of casein, TiO2 nanoparticles, and hydrophobic agents. As a result, the therapy of casein appears favourable for preventing second-degree burns from low intensity heat flux accidents such as cigarette fires.

High-Effective Casein-Based P-N Flame Retardants for Cotton Fabrics with Multiple Reactive Groups.

Casein-based FRs, which include reactive groups and are halogen-free, were synthesised using a casein hydrolysis solution for cotton textiles. Cotton textiles treated with casein-based FRs achieved strong flame retardancy, with a limiting oxygen index (LOI) of 39.5%. Compared to existing natural flame retardants, new flame retardants can provide long-lasting flame retardancy to cotton materials. The LOI value remained at 26.7% after 40 washing cycles (LC). Cotton textiles treated with casein-based FRs shown significantly improved flame retardancy, as proven by cone calorimetry and vertical burning tests. X-ray photoelectron spectroscopy (XPS) and Fourier-transform infrared (FTIR) analysis revealed that casein-based FRs were grafted onto cellulose via P(O)−O−C and C(O)−O−C bonds. SEM analysis confirmed that the alteration was simple. Thermogravimetry (TG), energy-dispersive X-ray (EDX), TG-FTIR, and SEM analysis showed that casein-based FRs were effective in both condensed and gaseous phases, having flame retardant properties. Casein-based FRs inhibited levoglucosan production and facilitated cellulose dehydration. Cotton textiles treated with casein-based FRs maintained high tensile strength and whiteness.

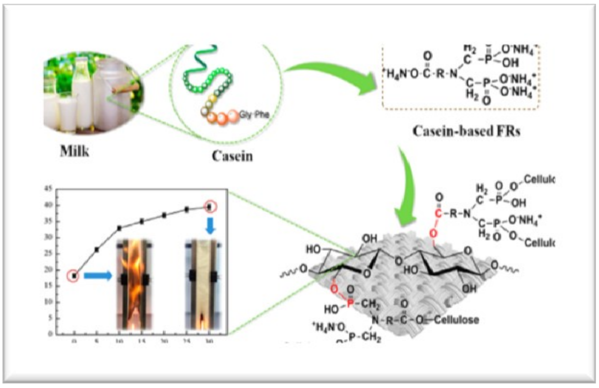

Figure 2: Concentrations of Casein-based FRs [15]

providing UV protection, enhanced performance, and antibacterial activity to polyester fabrics treated with casein

The textile industry frequently uses polyester fibres because of their compatibility, low cost, ease of maintenance, and longevity. Because of its hydrophobic qualities, polyester is not as comfortable and cannot be used for most textile applications, including undergarments, sportswear, and sleeping.

Research into the necessity of improving polyester's properties to meet market demands is therefore becoming more and more interested. In the current study, casein was applied on the surface of knitted and woven polyester textiles to offer them additional desirable properties. The textiles were prepared with sodium hydroxide using the pad-dry-cure method, and then they were treated directly with casein in various concentrations of epichlorohydrin, which was used as a cross-linker.

The different dissolved casein concentrations' apparent viscosities The viscosity of the dissolved casein biopolymer at different concentrations was examined. The morphological structure of the treated and untreated polyester textiles was investigated using field emission scanning electron microscopy (FE-SEM) and dispersive X-ray spectroscopy (EDX), respectively. The mechanical and physical properties of the treated and untreated textiles were investigated, as well as their base combining capacity was evaluated and compared, in order to evaluate their performance.

Furthermore, an analysis was conducted to compare the antibacterial activity of treated and untreated fibres. The results indicated that all treated polyester textiles had better moisture recovery, UPF, antistatic, and antibacterial properties than the untreated materials. Electrostatic charges were increased, surface roughness was decreased, and strength parameters were improved in polyester samples that were knitted, woven, and treated alone with casein. However, compared to the woven samples that were first treated with sodium hydroxide and subsequently casein, the knitted samples showed lower values and increased stiffness. An overall examination of the significant qualities of all treated polyester fabrics revealed that the woven sample pretreated with 10% NaOH and 7% casein alone, and the knitted sample treated with 4% casein, had the best functional performance. [16]

Antibacterial Textile Based on Hydrolyzed Milk Casein

The natural substance hydrolyzed casein and polypropylene (PP) are the building blocks of antimicrobial textile constructions; yarns and a knitting fabric were successfully made from a blend of PP with 5 wt.% hydrolyzed casein; the latter material demonstrated high efficiency as an antibacterial material; its antibacterial activity value was found to be higher than 6.4. In contrast, silver and ZnO are commonly used as antibacterial agents in textile materials; recently developed silver-based textile [17]. Staphylococcus aureus is one of the five distinct Gramme+ and Gram− bacterial strains that this novel textile material, Materials, containing ZnO nanoparticles, shown antibacterial activity values ranging from 1.2 to 4.0 towards. [18]. The rheological analysis prompts us to hypothesise physical interactions between the hydrolyzed casein's NH3 + groups; these contacts impede the blend's relaxing process but have no effect on the rheological behaviour of PP. But adding 5 weight percent hydrolyzed casein reduced viscosity at a high temperature. This distinction needs to be taken into account in any potential industrial process. The hydrolyzed casein chains with NH3 + groups and the matrix's hydrocarbon chains differed in their hydrophilic/hydrophobic nature, which appeared to have a little impact on the PP's mechanical characteristics. This effect was most pronounced for the filaments. This problem may be resolved in the future by including an appropriate compatibilizer into the mixture. When comparing the resultant knit to neat PP, no moisture retention was seen; this is an important characteristic for textile materials.

A pertinent benefit for the contemporary environmental context, where ecologically friendly procedures are widely wanted, is that the textile material was manufactured in a melt process (extrusion and melt spinning) using straightforward techniques, in addition to the intriguing aspects already described. These findings support the idea that dairy waste may be recycled while also serving as a viable substitute for some of the antibacterial agents now in use that are synthetic, non-renewable, and detrimental to both human health and the environment. [19]

Conclusion

Casein is the primary emulsifier in milk, that is, it helps in mixing oils, fats, and water in milk. Casein is a flexible protein that may be used in many fields, especially the field of textile, in the production of fibers called milk fibers, offers several qualities that make it valuable in textile technology. Casein fiber is highly smooth, sheen, and delicate.

It absorbs moisture well due to its hygroscopic nature. Colorfast and Dyeable

It reacts like wool, allowing it to be dyed similarly. No special care is needed because of its natural protein base. Blending Potential: Casein fiber can be blended with other fibers, enhancing its quality. It Can be used also in textile as well as finishing processing such Antimicrobial, Flame-retardant, The durability, physiological comfort and UV protection casein combines eco-friendliness with practical applications in textile sector.

Funds

The author declares that there is no funder.

Conflict of Interest

There is no conflict of interest in the publication of this article.

Acknowledgements

The author thanks Benha University, Benha, Egypt

Reference

1. Kunz, C. and B. Lönnerdal, *Human-milk proteins: analysis of casein and casein subunits by anion-exchange chromatography, gel electrophoresis, and specific staining methods.* The American journal of clinical nutrition, 1990. **51**(1): p. 37-46.
2. Braun, K., A. Hanewald, and T.A. Vilgis, *Milk emulsions: Structure and stability.* Foods, 2019. **8**(10): p. 483.
3. Farrell Jr, H.M., *Models for casein micelle formation.* Journal of Dairy Science, 1973. **56**(9): p. 1195-1206.
4. Dalgleish, D.G., *Casein micelles as colloids: surface structures and stabilities.* Journal of dairy science, 1998. **81**(11): p. 3013-3018.
5. Holt, C., *Structure and stability of bovine casein micelles.* Advances in protein chemistry, 1992. **43**: p. 63-151.
6. Weiss, D. and S. Chace, *Reader's digest crafts & hobbies*. 1979: Readers Digest.
7. Patni, N., N. Tripathi, and S. Bosmia, *Casein Extraction from various milk samples and its role as a viable substitute for conventional plastics.* Int. J. Appl. Eng. Res, 2013. **8**: p. 10-13.
8. Agarwal, O.P., *Advances Practical Oraganic Chemistry*. 2006: Krishna Prakashan Media.
9. Garg, A., et al., *Mapping the acceptance of Indian footwear industry for "Vocal for Local-A Sustainable Paradigm".* S. No. Title of Paper Page No.: p. 142.
10. Kolanjikombil, M., *The Substrates--Textile, Yarn and Fabric*. 2020: WPI Publishing.
11. Tasnim, N., *Eco-friendly manufacturing process of casein fiber with it's sustainable features & comfortable uses.* American Journal of Environmental Engineering, 2019. **9**(2): p. 31-35.
12. Bechtold, T. and T. Pham, *Textile chemistry*. 2019: Walter de Gruyter GmbH & Co KG.
13. Benli, H. and M.İ. Bahtiyari, *Dyeing of casein fibers with onion skin-based natural dye sources after ozonation.* Ozone: Science & Engineering, 2018. **40**(2): p. 141-147.
14. Minaei, F., et al., *The fabrication and characterization of casein/PEO nanofibrous yarn via electrospinning.* e-Polymers, 2019. **19**(1): p. 154-167.
15. Xu, F., et al., *Novel high-efficiency casein-based P–N-containing flame retardants with multiple reactive groups for cotton fabrics.* ACS sustainable chemistry & engineering, 2019. **7**(16): p. 13999-14008.
16. Ali, M.A., N.M. Aly, and A.A. Abou El-Kheir, *Imparting antibacterial activity, UV-protection properties and enhancing performance of casein modified polyester fabrics.* The Journal of The Textile Institute, 2021. **112**(9): p. 1436-1448.
17. Owen, L. and K. Laird, *Development of a silver-based dual-function antimicrobial laundry additive and textile coating for the decontamination of healthcare laundry.* Journal of Applied Microbiology, 2021. **130**(4): p. 1012-1022.
18. d'Água, R.B., et al., *Efficient coverage of ZnO nanoparticles on cotton fibres for antibacterial finishing using a rapid and low cost in situ synthesis.* New Journal of Chemistry, 2018. **42**(2): p. 1052-1060.
19. Belkhir, K., et al., *Antibacterial textile based on hydrolyzed milk casein.* Materials, 2021. **14**(2): p. 251.