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PRODUCTION AND CHARACTERIZATION OF KERATIN–CHITOSAN COMPOSITE BIOPLASTIC FILM FROM POULTRY AND FISH-SCALE BIOMASS FOR SUSTAINABLE FOOD PACKAGING

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ABSTRACT

Background: The rising accumulation of non-biodegradable plastic garbage has caused enormous environmental challenges, demanding the development of sustainable alternatives. Keratin and chitosan produced from poultry feathers and fish-scale waste represent promising renewable biopolymers for biodegradable food-packaging applications.

Methods: The chicken feathers were used for keratin extraction while the fish scales were demineralised, deproteinised and deacetylated to obtain chitosan. The biopolymers were removed and then mixed with glycerol and composite films were fabricated. Characterization of the films was done by Scanning Electron Microscopy (SEM), Fourier Transform Infrared Spectroscopy (FTIR), Thermogravimetric Analysis (TGA) and X-ray Fluorescence (XRF). Soil-burial tests and chemical resistance tests were also carried out.

Result: The composite film was formed in a uniform shape with distinct functional groups, demonstrating successful interaction between keratin and chitosan that was successfully synthesized. Thermogravimetric analyses revealed that the degradation temperatures were 59.67%, 14.39% and 11.85% during the different degradation stages, which revealed good thermal stability. The lack of detectable harmful heavy metals, such as Cd, Pb, Cr, and Hg, was verified by XRF analysis. The film retained its structural stability in diluted environments of acidic, alkaline, saline and ethanol solutions. Soil-burial tests show good biodegradability after 60 days, with a weight loss of approximately 78.2%.

Conclusion: Fish and poultry waste-based keratin–chitosan composite film exhibited promising physicochemical properties and biodegradability, promising it a sustainable biodegradable packaging material.

KEYWORDS: Bioplastic, Keratin, Chitosan, Chicken feathers, Fish Scales, Sustainable Food Packaging.

1. INTRODUCTION

Synthetic polymers are widely utilised due to their superior mechanical qualities, durability, cost-effectiveness, and ease of production. (Bahl et al., 2021). These non-degradable synthetic polymers cause harmful contaminating effects on the environment (Shah et al., 2024). The recent United Nations convention review report stated that over 600 different varieties of marine species are affected by marine plastic waste mainly via consumption (Shah et al., 2024). The synthetic plastics production process involves the usage of chemicals like bisphenol, vinyl chloride, ethylene, and terephthalic acid. These chemicals cause health problems to human like placenta disruption during pregnancy, neurotoxicity, gastrointestinal issues, oxidative stress and fatal diseases like defects during birth, malignant tumours, and endocrine diseases (Kaushal et al., 2021).

The adverse effects of plastic pollution in the environment and health defects in plants, animals and human necessitating extensive search for recyclable substitutes to conventional synthetic polymers, leading to momentous investigation and improvement in the area of bioplastics (Pillai et al., 2024). Biopolymers are naturally degradable macromolecules obtained from sustainable or agricultural waste materials made up of repeating monomers linked by covalent bonds (Roy and Siracusa, 2023).

Bioplastics are sustainable materials derived from renewable natural resources like slowly degrading biopolymers, involve low-energy manufacturing processes, and simultaneously involve the removal of unwanted byproducts. The major challenges in the production of bioplastics for manufacturers and consumers for usage are adaptability to the existing manufacturing line, performance, and cost (Zhao et al., 2023). Bioplastics are acquired from biopolymers not only to moderate environmental effects but also to support circular-economy models (Rosenboom et al 2022).

Chitin is a second natural biopolymer present in nature after cellulose, which makes the exoskeletons of Arthropods of includes insects, spiders, Crustaceans like crabs, shrimp, and lobsters, and structural parts in Molluscs, present in yeast and fungal cell walls (Shahbaz 2020). Chitin is produced in huge amounts, like 10^{-11} metric tons yearly, and is made up of repeated units of a monomer called (1-4)-linked 2-acetamido-2-deoxy-β-D-glucose (Elieh-ali-komi and Hamblin 2016). But only 150,000 tons out of 10^{-11} metric tons are accessible for profitable use (Guan et al., 2019). Around 3/4 of the weight of discarded leftovers of crustaceans, ineffective solid waste management protocols, and dumped waste created unwanted changes to the environment. Developed countries followed landfilling and burning practices; others simply left them for natural degradation, which is dumped in the sea (Onyeaka et al., 2022). The usage of this chitin waste for the extraction of chitosan may reduce environmental pollution at the same time, which facilitates value addition (Priyadarshi and Rhim, 2020). Among such biopolymers, chitosan, obtained via deacetylation of chitin from crustaceans, has gained prominence due to its biodegradability, biocompatibility, and intrinsic antimicrobial activity (Jiménez-Gómez and Cecillia, 2020). Keratin, a fibrous protein abundant in chicken feather waste, provides raw material for sustainable material design. Keratin was extracted by alkaline hydrolysis to cast compatible biofilms with natural plasticisers like glycerol (Sharma et al., 2018). Recent advances incorporate different reinforcement materials like fillers, Compatibilizers, plasticizers and Nano with biopolymers to create composite bioplastic films, which exhibit reinforced mechanical strength and improved barrier and thermal properties (Collazo-Bigliardi et al., 2018).

Most researchers have concentrated on individual biopolymers like chitosan, starch, cellulose, or keratin, while very little literature exists regarding the synergic effect of keratin and chitosan that is obtained completely from waste biomass. In this regard, it should be kept in mind that the number of poultry feathers and fish scales that are produced in enormous amounts all around the world are normally thrown away as environmental pollution. Even though composite films consisting of keratin and chitosan have been made previously (Tran and Mututuvari, 2015), very few researchers have attempted to make sustainable food packaging films using chicken feather waste and fish scale waste and evaluate their morphology, thermal stability, biodegradability, chemical resistance, and food safety properties (Zhang et al., 2025).

The current work pertains to the co-utilisation of two readily available industrial agro waste materials, such as chicken feathers and fish scales, for making a bioplastic film from a keratin and chitosan bio composite using a straightforward solvent casting method. As against regular bioplastics made from single polymer sources, the current bioplastic film from the composite combines the qualities of proteins such as keratin with the film-forming property of chitosan, which gives rise to an environmentally friendly, heat-stable, and non-toxic material. Such dual valorisation of industrial agro wastes not only addresses the issue of waste but also facilitates the production of sustainable food packaging materials based on the circular bio economy principles (Nanda and Dalal 2023).

1.1. AIM:

To develop and characterize an eco-friendly keratin–chitosan composite bioplastic film from poultry feather and fish-scale biomass and evaluate its potential as a sustainable food packaging material.

1.2. Objective

- To isolate keratin from chicken feathers and chitosan from fish scales, and to build a keratin–chitosan composite bioplastic film utilising the solvent casting technique.
- To characterize the synthesized bioplastic film by assessing its morphological, chemical, thermal, and elemental properties by SEM, FTIR, TGA, and XRF investigations.
- To evaluate the appropriateness of the formulated bioplastic film for sustainable food packaging by examining its biodegradability, chemical resistance, and food safety attributes.

1.3. Research Gap

Keratin-based and chitosan-based films have both been described on their own, but there aren't many studies that use keratin from chicken feathers and chitosan from fish scales together for sustainable food packaging. Furthermore, a full analysis of the temperature stability, biodegradability, chemical resistance, and elemental safety of these two types of waste-derived composite films has not been shared very often.

2. MATERIALS AND METHODS

2.1. Sample collection and pre-treatment

The fish scales were collected from a local fish market and chicken feathers from a local chicken shop. The fish scales were cleaned multiple times to remove the sand particles and other impurities like fish blood and skin. The washed fish scales were left to dry at 40°C for 52 hours in the hot air oven (Uma shankari et al., 2024). The chicken feathers were cleaned multiple times with tap water and distilled water to remove the blood, sand and other impurities. This process was repeated until the colour of the feathers turned white, showing that it was free of impurities. The clean feathers were incubated overnight in an oven at 40 °C for drying (Ahmed et al., 2019).

2.2. Extraction of Keratin

To deglaze the chicken feathers, 100g was weighed and sliced into small pieces (10–30 cm) and was completely immersed in petroleum ether for 24 hours in a rotary shaker. Then the cut pieces of feathers were washed multiple times with distilled water to remove the petroleum ether completely (Kamarudin et al., 2017). Cleaned defatted feathers were kept in a hot air oven for 24 h for drying and chopped further into very small pieces of 2- 5 cm in size and stored at 4ºC for further use (Sharma et al., 2018). The degreased feathers were further immersed in 500 mM sodium sulfide and digested using a mechanical stirrer for 1–6 h (Ramalingum, 2021). The sodium sulfide-digested feathers were filtered twice using Whatman filter (110 mm) paper. The filtrate was then centrifuged at 5000 RPM for 30 min to get the supernatant free of feathers. This step was repeated multiple times in order to extract keratin with no impurities. The keratin particles were collected and dried overnight, then blended using a Prestige mixer grinder to get fine Keratin powder. A total of 47g of keratin powder was obtained from 100g of chicken feathers, with a yield of 47% (W/W), stored at 4ºC for further use (Sharma et al., 2018).

2.3. Extraction of chitosan

The pre-treated fish scales were used to extract chitosan by following demineralization, decolourization and deacetylation. For demineralization the fish scales (100g) were dipped in 500 mL of Hydrochloric acid (HCl) (1 M) for 20 hours. Further, 60g of squashy fish scales were added to 30ml of 38% HCl for 24hours. It was then washed and dried overnight in the oven at 30°C. After complete dry the scales were kept for demineralisation with Sodium Hydroxide (NaOH) (1:1 m/v) for 36 hours. The fish scales were dissolved in Potassium hydroxide (KOH) solution for 1 hour, followed by treatment with citric acid for decolouration. The end product was deacetylated further with 50% w/v NaOH to produce chitosan as the end product. Chitosan was centrifuged, and the supernatant was centrifuged again for 25 minutes. The resulting particles were dried in the hot air oven overnight. The chitosan extraction from 110g of fish scales yielded 53% (W/W) (Rahman et al., 2023).

2.4. Preparation for Bioplastic Film

Bioplastic film was prepared by following the procedures reported by (Sharma et al., 2018) with a few modifications. For bioplastic preparation, 500 mL of 3% acetic acid was prepared, followed by the addition of 35g of keratin powder (7% w/v), chitosan 10 g, 2% w/v) and approximately 1.6g of glycerol. The mixture was kept in the mechanical stirrer for 10 minutes at a constant temperature of 70 to 100ºC to get a bioplastic film. Then the solution was cooled a little and poured onto a plastic sheet that was greased with a greasing agent. The film was set to dry in the hot air oven at 40ºC for 48- 52 h. The film was peeled off from the plastic and analyzed for various properties (Lan et al., 2018). The bioplastic film-forming mixture was added with a food colour dye, saffron and Tween 80 to check the effect on the visual appearance of the films.

2.5. CHARACTERIZATION OF BIOPLASTIC FILM

2.5.1 Scanning Electron Microscopy (SEM)

The bioplastic film was analyzed for its surface morphology by Scanning Electron Microscopy (SEM). A small portion of the bioplastic film was directly mounted on the SEM- TM3030 with a voltage of 15 kV. The main consideration for getting a greater quality picture is that the sample kept for study should conduct electricity. SEM analysis helps us to check that the used molecules are well-mixed during the polymerization procedure (Ramakrishnan et al., 2018).

2.5.1. FTIR

The FTIR (Fourier Transform Infrared) analyzer used the transmission wavelength range between 4000-500 cm^{-1}. Fragments of bioplastic were dried and cleaned to eliminate all the unwanted debris found on their surface. FTIR was used to distinguish the functional groups found in the produced product. The deviation in peaks and wavenumbers delivers valuable details about the chemicals found in the polymeric structure, the specific degradation process of keratin and chitosan and the effect of the plasticisers used in the film and its structure (Krishnamurthy et al., 2019).

2.5.2. XRF/ Food Safety Test

The keratin-chitosan films' elemental composition was analysed qualitatively by XRF (X-Ray Fluorescence). These analyzers detect all types of elements from sodium to uranium simultaneously, with immediate output of good-quality spectra. The heavy metal measurements in the bioplastic composition are helpful to provide food security for the product (Dasumiati et al., 2019).

2.5.3. Thermogravimetric Analysis (TGA)

The bioplastic films' thermal stability was analysed by the TGA method. These data are used to determine the optimum conditions of bioplastic packaging when exposed to high temperatures or the resistance of the packaging in wrapping the food (Gbadeyan et al., 2022). For TGA analysis, the film was made into small pieces (2.5 to 5 mm) and placed on the sample holder for thermal stability analysis.

2.5.4. Chemical Resistance Evaluation

Four small pieces of bioplastic film 2 X 2 cm in size was taken, each piece was immersed in four different chemicals namely NaOH (0.1%), Sodium Chloride (NaCl) (0.1%), Ethanol (0.1%) Hcl (0.01%) and incubated for 48 hours to observe their physical changes due to chemical reactivity in alkaline and acidic natures by immersion method (Noyon et al., 2023).

2.5.5. Biodegradability Test

The bioplastic film was evaluated for its biodegradability using 5 pieces of film each (30 mm x 30 mm) in size

(Rahman et al., 2023). The prepared films were immersed in 5 separate Petri plates containing soil, and watering was done daily to maintain humidity. This setup was kept for 50 days, and the weight loss percentage was calculated at 10-day intervals. The biodegradation rate was calculated by measuring the weight loss percentage, stating the perceptions of the bioplastic films' environmental impact and eco-friendliness.

3. RESULTS AND DISCUSSION

To emphasise the bioplastic film preparation using chitosan and keratin, the keratin obtained from the chicken feathers was hydrolysed by 500 mM of sodium sulphide into peptides and amino acids. The chitosan was obtained from fish scales by demineralisation, decolouration and deacetylation processes. The obtained keratin and chitosan **(Figure 1)** were solubilized by mixing with 3% acetic acid in water. Then the mixture was added with 2%glycerol made as homogenous solution, then cast to get a transparent, flexible film **(Figure 2a).**

The fabrication of keratin and chitosan bioplastic film using the poultry feather and fish scale waste biomass has been shown to be feasible for producing bioplastics from less exploited biomaterials. The development of the strong composite film can be associated with intermolecular interactions that form between keratin and chitosan polymers. Intermolecular interactions between amino, hydroxyl, and carboxyl groups have been found to upgrade the structural stability and capacity to form films by protein-polysaccharide composites (Wang et al., 2024).

In a similar study, the film made with keratin with 10-30 wt% more chitosan was flexible, strong (27±8 MPa), with high elongation (4±2%) and Young's modulus (152±76 MPa). Adding 20 wt% of glycerol with keratin gave high flexibility with strength (1MPa) and elongation (28%). These reports documented that chitosan was mainly for increasing the elongation and strength of keratin film, and glycerol was found to enhance the elasticity. Hence, a suitable combination of chitosan and glycerol might regulate the mechanical strength of keratin film (Salleh and Abd Rashid, 2024).

The visual appearance of the films was studied with the addition of food colour saffron and Tween 80. Saffron was added for commercial marketing purposes, and it was observed that it did not affect the stability of the film and also retained its shape and structure. The film was yellow and vibrant-looking **(Figure 2b).** Tween 80 is widely used as a plasticizer in the bioplastic industry. To check its effect on biofilm appearance, 0.2% Tween 80 were added to the original compositions of the bioplastic solution; this film was more ductile and had a greasy texture. Tween 80 also gave the film a slightly more of an added yellow colour **(Figure 2c).**

Scanning electron microscopy image **(Figure 3)** of the keratin-chitosan film was used to recognize their surface texture, layering, homogeneity and voids. SEM analysis was done for the bioplastic film at various magnifications like 501X, 200X, 1.00KX, 2.50KX. The SEM images of the biofilm presented a coarse surface with a various interlocked network of internal constituents. The external surface of the film looked rough and uneven, which suggests the nature of chitosan and keratin. The rough surface is potential for various applications requiring specific surface characteristics (Ocak 2024).

The SEM analysis showed a relatively homogeneous and dense surface morphology, representing good compatibility of the extracted keratin with the chitosan matrix. In an earlier study, keratin films with a compact surface structure have been reported for better mechanical and barrier properties due to homogeneous distribution of the polymers (Feroz et al., 2021).

The images also revealed the occurrence of various microstructures, with evidence of some circular spots on the film with a dimension range of a few 100 nm, probably composed of chitosan. However, the addition of glycerol evenly dispersed on the top layer of the film shows some level of consistency within the keratin chitosan bioplastic film. The images of **(Figure.3)** show that the presence of voids and distortions is due to the plasticiser content present and proves that form less voids and undispersed particles at lower plasticiser content.

This finding aligns with the study of ZnONPs-coated chitosan films to study the spreading of ZnONPs in the chitosan-PVA film. There were many white spots appearing on the chitosan film upon the incorporation of ZnONPs approving its uniformity in various studies (Abdullahi et al., 2025). The ZnONPs provide a cohesive nature, and their molecular level is successfully dispersed, which helps improve the packaging nature of the film. The voids and the separation present in the images are directly proportional to the glycerol content present.

The FTIR spectrum **(Figure 4)** shows the main diagnostic peaks in the wavenumber range between 4000cm-1 to 400cm-1. The major peaks are reported at 3428.81cm-1, 2365.26cm-1, and multiple other smaller peaks in different wavenumbers. In the presence of a plasticiser, the graph shows a shifting peak towards a higher wavenumber. This is because of the decreased interaction of glycerol with keratin chitosan polymers. The amide II bands composition N-H bending and C-N stretching vibrations, are observed at 1548.56 cm-1 **(Table 1)**. Amide II undergo conformational changes more readily than amide I; the N-H group is much more sensitive to the environment (Dahlburg et al., 2016). Therefore, the amide II band can be used to assume alterations in the environment of the N-H groups with respect to hydrogen-bonding environments (AI Mamum and Chen, 2020).

Commonly, the heavy hydrogen-bonded N-H groups show high frequency peaks. The hydroxyl groups of glycerol can form a higher number of hydrogen bonds, thus accumulating the number of hydrogen-bonded peptide groups (Ocak, 2024). Therefore, the N-H groups are observed at a higher wavenumber in the spectrum. There are clusters of peaks observed below 2000cm^{-1} to 400cm-' are due to the stretching of sp2-hybridised C-H bonds. There is a collection of peaks around 3300cm-[1] formed by alcohol O-H bonded groups. At 1650 cm-1, there is a sharp peak observed due to the presence of carboxylic acids in the combination. However, the criteria of the peaks meet the existence of carbonyl peak, alkyl peaks and ester peaks (Tran and Mututuvari 2015).

The spectral data show the presence of typical functional groups, indicating the successful mixing of the keratin and chitosan biopolymers. Similar spectral changes caused by hydrogen bonding and electrostatic interactions have been found in earlier keratin and chitosan composite films (Sharma and Nadda, 2024). These interactions are known to provide a more cohesive nature and stability for the biodegradable films.

The TGA was used to determine the film stability towards heat and the presence of evaporative substances by observing the change of weight during heating at a constant rate. This curve depicts three stages of decomposition **(Figure 5)**. The first stage of decomposition occurred at 90-360℃ temperature range, with a weight loss of 59.67%. The water content of the biofilm is removed below 100°C. At the temperature range of 110–300 °C, the organic pollutants present in the sample as a liquid phase evaporate. The degradation above 300-360 °C is associated with the pyrolytic decomposition of linkages and depolymerisation of chitin and keratin. The second stage of decomposition occurred at 370- 600 °C, with less weight reduction of 14.39% due to high volatile component loss. The third stage of degradation shows 11.85% weight loss in the temperature range of above 600-900 is due to the loss of residual compounds like the polymer. These results show that bioplastic film can withstand temperatures above 100°C, suits to pack too hot foods.

The thermal behaviour of a bio fibre made up of chitosan-starch/short keratin bio fibre (ChS-SB) was described in three main steps (Che et al. 2016). In the first stage, (7%) of weight loss was observed in the range of 30–135°C due to loss of bound water. There was a great mass reduction (8% to 76%) observed at 220–360 °C in the second stage due to dehydration of the saccharide rings, depolymerisation, and decomposition of the chitosan units. In the third step, complete degradation of the polymer occurred between 450–600 °C (Chen et al., 2016).

The XRF data (**Table 2)** show that the sample has calcium, sodium, manganese, iron, copper, zinc and osmium. The XRF result indicates that the bioplastic film does not contain Cd, Pb, Cr and Hg, like heavy metals. It confirms that this bioplastic film does not cause any ill effects during consumption and hence can be used in the food industry for non-toxic food packaging. At the same time, the major content in this material is calcium, which is a mineral very essential to human beings. This is primarily due to the keratin content of the biofilm, which is derived from the feathers of Chickens. When the Food is packed with the bioplastic, which has a composition of 2% chitosan, the lack of detectable heavy elements, such as cadmium, lead, chromium, and mercury, signifies that the produced bioplastic film has a commendable elemental safety profile. Nonetheless, the mere absence of heavy metals is inadequate to confirm food-contact safety (Younis et al., 2026).

The chemical resistance of the bioplastic was evaluated by treating the film in different chemicals in diluted concentrations for 48 hours, and the change in physical nature was observed. In NaOH, the film underwent some structural changes and was not dissolved. In 0.1% NaCl, after 48 hours of incubation, the film did not lose its integrity without any visible deterioration, such as swelling. In 0.01% HCl, the bioplastic film maintained its integrity without notable dissolution. In ethanol, the film did not develop any observable swelling, deformation and structural integrity. These results show that this biofilm suits dry, low-moisture, refrigerated acidic, alkali and oily foods.

The Bioplastic film was buried under natural soil with proper moisture maintenance and was observed for the rate of biodegradation for a period of 50 days **(Figure 6).** Soil burial testing is one of the authoritative methods providing critical understandings of bioplastics degradation level and its overall environmental compatibility (Hasan Ahmed et al., 2025; Luchese et al., 2018). The degradation rate was analysed at ten-day intervals by estimating the percentage of weight loss of the biofilm. There was an exponential weight loss rate observed, approximately 78.2%, after 60 days of burial. In a similar study, chitosan bioplastic displayed a weight loss rate of approximately 80.92% (Rezaei et al., 2023) during soil burial testing.

Consuming feathers and fish scales as raw materials is aligned with present tendencies towards the development of sustainable biomaterials and bio-based circular economy strategies. Recent scientific works show that the valorisation of agro-industrial waste into biodegradable packaging materials could considerably decrease pollution caused by traditional plastic and increase resource efficiency (Hasan Ahmed et al., 2025). Thus, this work can be seen as part of the recent scientific development dedicated to waste-derived biopolymers recycled in packaging applications.

There are numerous benefits to this developed keratin–chitosan composite film. First, it uses abundant and inexpensive biomass waste resources, which supports resolving the problem of its dumping. Second, both chitosan and keratin are biodegradable and renewable biopolymers and can become eco-friendly alternatives for petroleum-based plastics (Arif et al., 2023). Third, the complex itself might help to increase the film strength through interaction of the protein and polysaccharide matrices. Finally, it is possible to use circular economy practices when converting chicken and fish processing waste into packaging material (Nanda et al., 2023). However, more investigation in terms of food safety and packaging of foods is mandatory for authorisation by the European Food Safety Authority (EFSA, Zhang et al., 2025).

4. CONCLUSION

The current study focused on the production of an eco-friendly biofilm from recyclable biomass waste to attain sustainability. The non-toxic biofilm was produced using keratin from chicken feathers and chitosan from fish scales. The composite mixture used for biofilm making shared similar properties in line with literature regarding biodegradable protein-polysaccharide matrices. The SEM and FTIR analysis confirmed that the keratin and chitosan have efficiently developed an interaction in the matrix lead to strong homogenous surface and a stable film. Likewise, the XRF analysis reported the absence of any tested heavy metals. However, the heavy metal absence not only enough to prove the safety of the film when it comes to contact with food, and there is a need for confirmation regarding toxicological and migration tests. The film showed high thermal stability and rapid biodegradability in natural soil conditions. The material passed basic food safety standards and resisted effective chemical exposure, highlighting its wide application in sustainable packaging solutions. The results confirmed that this product is suitable for packaging of dry, low-moisture, refrigerated, acidic, alkaline, and oily food products.

The film showed promise, but mechanical strength, barrier performance, migratory behaviour, food-contact safety, shelf-life, and scalability must be studied before industrial use. Keratin–chitosan composite film supports waste valorisation and circular bioeconomy while providing a sustainable, biodegradable alternative to petroleum-based plastics.

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Abbreviation:

S. No	Abbreviation	Full Form
1	SEM	Scanning Electron Microscopy
2	FTIR	Fourier Transform Infrared
3	XRF	X-Ray Fluorescence
5	TGA	Thermal Gravimetric Analyser
6	KOH	Potassium hydroxide
7	NaOH	Sodium Hydroxide
8	HCl	Hydrochloric acid
9	NaCl	Sodium Chloride
10	RPM	Rotation Per Minute
11	mM	Milli Molar

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