SURFACES ROUGHNESS AND MICROSTRUCTURE STUDIES ON EGGSHELL SURFACES/BANANA INNER TRUNK SKIN TEXTURE

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Declaration

Candidate's Declaration

I hereby declare that this thesis is the result of my original work and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature	:____________________________
Name	:____________________________
Date	:____________________________

Supervisor's Declaration

I hereby declare that the preparation and presentation of thesis were supervised in accordance with guidelines on supervision of thesis laid down by Universiti Sains Malaysia.

Supervisor's Signature	:____________________________
Name	:____________________________
Date	:____________________________

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Table of Contents

List of Graphs

List of Tables

List of Equations

List of Figures

Nomenclature

AFM	Atomic Force Microscope
Al	Aluminium
ALP	Alpedrete
B	Banana Inner Trunk
BF	Basaltic Filler
Br	Bromine
C	Carbon
C.F.R.	Short Wave Filter
Ca	Calcium
$CaCO_3$	Calcium Carbonate
Ch	Chicken
Cl	Chlorine
D	Duck
EDAX	Energy Dispersive Spectroscopy
FD	Fractal Dimension
Fext	External Fibre
Fint	Internal Fibre
Finterm	Intermediate Fibre
G, BG	Growth Stage
GF	Glass Fibres
H	Hydraulic Lime
HA	Hot Air
H-Div.	Horizontal Division
HDPE	High-density Polyethylene
HIC	Hydrogen Induced Cracking
HL	Hydrated Lime
H-Mag	Horizontal Magnification
ICPD	Instant Controlled Pressure Drop Process
K	Potassium
L	Evaluation Length
LCL	Lower Limit Control
LF	Limestone Filler

LMR	Lightly Milled Rice	
M, BM	Maturation Stage	
M. Speed	Measurement Speed	mm/s
Meas. Range	Measurement Range	µm
Mg	Magnesium	
MM	Man-made	
N	Natural	
Na	Sodium	
Na_2SO_4	Sodium Sulfate	
O	Oxygen	
P	Phosphorus	
PC	Portland Cement	
pHEMA	Poly (2-hydroxyethyl methacrylate)	
Q	Quail	
RMS	Root Mean Square	
R_z	Ten-point Mean Roughness	
S	Sulfur	
S, BS	Senescence Stage	
S_a, R_a	Arithmetical Mean Roughness	nm; µm
SEM	Scanning Electron Microscopy	
SI	Surface Intensity	
Si	Silicon	
S_q, R_q	Root Mean Square Roughness	µm
SS	Superheated Stream	
STM	Scanning Tunneling Microscope	
UCL	Upper Limit Control	
V-Div.	Vertical Division	
V-Mag	Vertical Magnification	
XRD	X-Ray Diffraction	
Z(x)	Profile Height Function	
ZAR	Zarzalejo	

Abstrak (Bahasa Malaysia)

Telur dan pisang dimakan oleh manusia dalam kehidupan harian. Ini bermakna banyak kulit telur telah dibuang dan pokok pisang telah ditebang sebagai sisa buangan. Kulit telur (Ayam, Ch; Itik, D; dan Puyuh, Q) sentiasa disalahsangkakan bahawa ia tidak sesuai dijadikan salah satu bahan kejuruteraan berdasarkan kerapuhannya dan serat yang diekstrak daripada dalaman batang pisang(B) juga disalahsangkakan bahawa ia tidak cukup kuat berdasarkan sifat-sfiat lembut dan basahnya. Tujuan kertas kerja ini adalah untuk menggambarkan kekasaran permukaan dengan menggunakan profilometer dan kajian mikrostruktur pada pelbagai jenis kulit telur dan dalaman batang pisang berdasarkan peringkat kematangan (Pertumbuhan, G; Kematangan, M; dan Ketuaan, S) atas tekstur permukaan dengan menggunakan Mikroskop Imbasan Elektron (SEM) dan menerokai aplikasi kejuruteraan terhadap kulit telur dan dalaman batang pisang. Agihan dan ketebalan membran sel organik dilekat pada kulit telur menentukan kekasaran permukaan dalam kulit telur (Ch: R_a=1.247μm, R_q=1.606μm; D: R_a=1.171μm, R_q=1.449μm; Q: R_a=1.237μm, R_q=1.561μm) dan saiz zarah menentukan kekasaran permukaan luar kulit telur (Ch: R_a=1.327μm, R_q=1.645μm; D: R_a=1.170μm, R_q=1.585μm; Q: R_a=1.627μm, R_q=2.057μm). Ciri-ciri selulosa adalah salah satu faktor yang mempengaruhi kekasaran permukaan dalaman batang pisang dari arah sisi (Permukaan dalam: {BG: R_a=1.237μm, R_q=1.568μm; BM: R_a=1.807μm, R_q=2.249μm; BS: R_a=11.203μm, R_q=14.973μm}; Permukaan luar: {BG: R_a=0.832μm, R_q=1.020μm; BM: R_a=1.267μm, R_q=1.553μm; BS: R_a=17.166μm, R_q=20.837μm}) dan membujur (Permukaan dalam: {BG: R_a=1.140μm, R_q=1.418μm; BM: R_a=1.354μm, R_q=1.668μm; BS: R_a=3.593μm, R_q=4.411μm}; Permukaan luar: {BG: R_a=0.515μm, R_q=0.654μm; BM: R_a=0.862μm, R_q=1.090μm; BS: R_a=1.531μm, R_q=1.942μm}). Penerokaan baru tentang bahan-bahan ini akan mewujudkan persekitaran yang bersih dan sihat dan menjurus pada sasaran sisa sifar dengan mengitar semula bahan-bahan ini untuk dijadikan sebagai aplikasi yang berguna.

Abstract (Bahasa Inggeris)

Eggs and bananas were consumed by human being in their daily life, which indicates that a lot of eggshells were being thrown and banana plants were cut down as waste. Eggshell (Chicken, Ch; Duck, D; and Quail, Q) was often wrongly believed being unsuitable to be one of engineering materials due to its brittleness and the fiber extracted from banana inner trunk (B) was also wrongly perceived as not strong enough because of its soft and wet properties. The aims of this reaserch were to describe the surface roughness by using surface profilometer and microstructure studies on each diversity of eggshell surfaces and inner banana trunk according their maturity stages (Growth, G, Maturation, M and Senescence, S) towards skin texture by using Scanning Electron Microscope (SEM) and to discover the further engineering applications of the eggshell and inner banana trunk. Distribution and thickness of organic cell membrane attached to the eggshell determined the surface roughness of the inner surface of the eggshell (Ch: R_a=1.247µm, R_q=1.606µm; D: R_a=1.171µm, R_q=1.449µm; Q: R_a=1.237µm, R_q=1.561µm) and grains size determined the surface roughness of the outer surface of eggshell (Ch: R_a=1.327µm, R_q=1.645µm; D: R_a=1.170µm, R_q=1.585µm; Q: R_a=1.627µm, R_q=2.057µm). Cellulosic properties were the factors affecting the surface roughness of the banana inner trunk in lateral (Inner Surface: {BG: R_a=1.237µm, R_q=1.568µm; BM: R_a=1.807µm, R_q=2.249µm; BS: R_a=11.203µm, R_q=14.973µm}; Outer Surface: {BG: R_a=0.832µm, R_q=1.020µm; BM: R_a=1.267µm, R_q=1.553µm; BS: R_a=17.166µm, R_q=20.837µm}) and longitudinal directions (Inner Surface: {BG: R_a=1.140µm, R_q=1.418µm; BM: R_a=1.354µm, R_q=1.668µm; BS: R_a=3.593µm, R_q=4.411µm}; Outer Surface: {BG: R_a=0.515µm, R_q=0.654µm; BM: R_a=0.862µm, R_q=1.090µm; BS: R_a=1.531µm, R_q=1.942µm}). New invention of these materials will able to create a zero waste environment by recycling these materials for useful applications.

Chapter 1 Introduction

Eggshell is a semi-permeable membrane that is made almost entirely of calcium carbonate ($CaCO_3$). It allows only the air and moisture to pass through its pores.[1] In general, eggshell consists of different layers which cannot be seen by human naked eyes.

Based on Figure 1.1, eggshell has four separate layers which are called as cuticle, prismatic layer, external layer and mammilla layer. Cuticle serves as the protection for embryo to keep out the bacteria and dust. The upper shell unit is made up by the prismatic layer and external layer, which is distinctly different from the mammilla layer. Along the calcite crystal boundaries, pores are present to provide the mechanism for gas exchange while the eggs are incubating. Organic shell membrane adheres to the mammilla layer. In fact, there are different types of eggshell in term of diversity such as duck egg, chicken egg and quail egg and etc. Eggshells of each species have different physical properties such as shapes, sizes, microstructures, and other properties that classify them.[2]

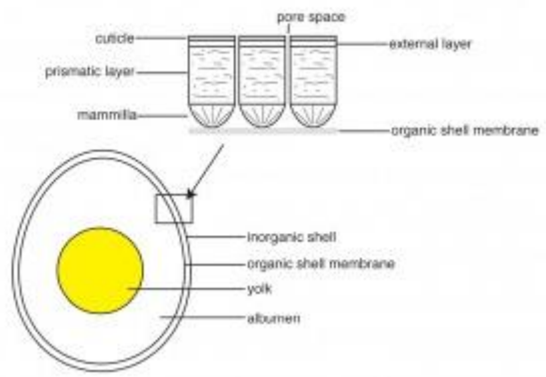

Figure 1.1 Microstructure of the egg and eggshell [3]

Banana is the common name for largest herbaceous flowering plants included in genus Musa which is one of two or three genera in the family Musaceae. From Figure 1.2, banana plant is a large herb, which is a giant perennial herbaceous monocotyledon.[4]

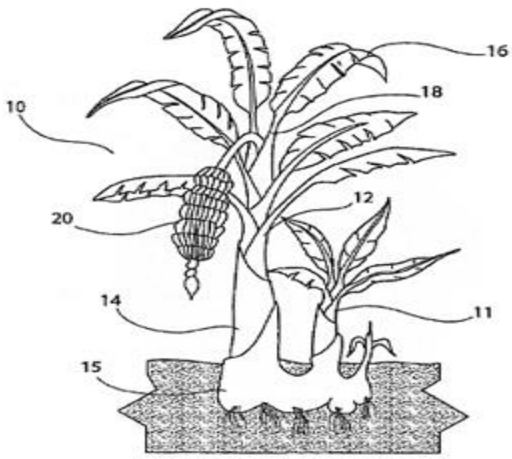

Figure 1.2: Banana plant[5]

From Figure 1.3, the banana trunk consists of two layers which are inner layer and outer layer (coarse). The structure of banana inner trunk is made by individual fibers. These individual fibers are extremely long and strong; extend from the base of the stem through the entire trunk. Banana functions as the renewable fiber.[5]

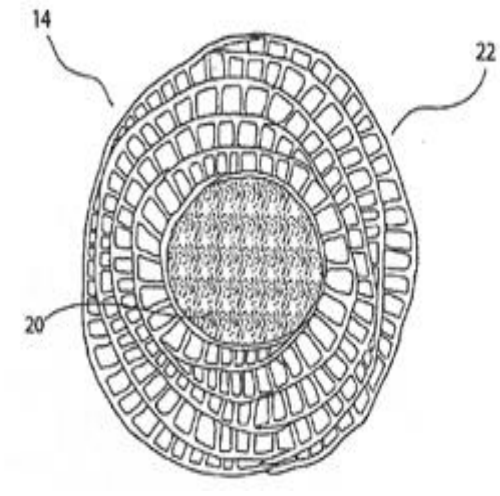

Figure 1.3: Cross sectional view of banana trunk[5]

Based on developmental stages of the plants[6], the banana plant will grow through from growth stages to maturation stage and finally to the senescence stage. Based on the observation on physical appearance of banana inner trunk, the banana inner trunk changes its color from green in growth stage and yellow in maturation stage until in the senescence stage, the banana inner trunk changes to brown in color.

However, eggshell is wrongly believed being unsuitable to be one of engineering materials such as used for building construction material due to its brittleness and it is commonly used as natural fertilizers/pesticides/composts. It is because the eggshell is too fragile and easily cracked due to large force. Other than that, inner banana trunk is commonly considered as a waste once the fruit has been harvested. They are normally chopped, disposed from the field, commonly left to rot and burned in open environment causing air pollution. The fiber extracted from inner banana trunk is wrongly perceived as not strong enough to be used as engineering material because of its soft and wet properties.

The main purpose of this research is to describe the surface roughness and microstructure studies on each diversity of eggshell surfaces and inner banana trunk according their maturity stages towards skin texture and to discover the further engineering applications of the eggshell and inner banana trunk instead of becoming a food waste from the observation of their surface roughness, microstructure and composition.

The motivation of this research is to achieve environmental sustainability by reusing and recycling resources and protecting the environment of the future from potential damage in order to provide an environment with less pollution.

The main objectives:

1. To determine and compare the surface roughness of banana trunk and eggshell
2. To observe and study the surface topography and their compositions

Chapter 2 Literature Review

In aspect of natural texture, earth's solid surface was represented as an essential part of our ecosystem. In the Earth, the most important element was the soil and it can be parameterized based on their consistency, dielectric and geometric properties. Meanwhile, its rough surfaces can be divided into two main groups; deterministic and randomly rough surface. The first one was the surface with a given profile that had periodic irregularities on its surface and the second one was the surface that had random irregularities on the surface. [7]

Many researches were done to describe the surface roughness of the natural texture. One of the researches was to compare surface roughness of the particles in the 2 species of the larva which were Psilotreta kisoensis and Perissoneura paradoxa larvae in order to test the hypothesis which was the standard for choices for a larval population inhibiting varies according to the availability of materials in the surrounding sediments. The larvae preferred to inhibit on the area that have a lot of smooth particle because it was more related to roughness of the available sediment particles, not related to surface roughness of their natural case particles. [8]

Besides that, surface quality quantification was done to compare two types of granites which were Zarzalejo (ZAR) granite and Alpedrete (ALP) granite before and after the Sodium Sulfate (Na_2SO_4) crystallization test. Before crystallization test, surface roughness value ZAR granite was higher than of ALP granite. Surface roughness value rose in both types of granites and the greater differences were determined in ZAR granites than ALP granites. The surface roughness values of the corner and edge of the specimen were higher than of the center of the specimen. This research provided a good impact on the future behavior of the stones which used commonly in historic buildings. [9] Some properties were influenced by the surface roughness such as brightness, reflectivity and color for optical properties and adherence, friction load capacity and resistance to the waste and slip for mechanical properties and will affect its durability. Roughness led to decay of the stone such as bio-deterioration, corrosion alteration of chemical composition, absorption and differential growth of salt and way the microorganism adhere to the surface. [10]

A study was done to compare about characteristic of the natural and man-made flooring material in order to describe both slip resistance. Potential for slip of flooring material was classified as high, moderate and low according to surface roughness value, R_z. [11] Table 2.1 shows the classification of potential for slip of flooring materials according to surface roughness value, R_z.

Table 2.1: Classification of potential for slip of flooring materials according to surface roughness value, R_z [11]

Potential for slip*	Flooring Material{N(Natural)/MM(Man-made)}
High	Polished Marble (N)
	Agglomerate (MM)
	Polished Granite (N)
	Terrazzo Natural Finish (MM)
	Unfilled Travertine Gloss Finish (N)
	Honed Limestone (N)
	Terrazzo Gloss Finish (MM)
	Artificial Slate Smooth Finish (MM)
Moderate	Polished Limestone (N)
	Unfilled Travertine Natural Finish (N)
Low	Riven Slate Gloss Finish (N)
	Pebble Mosaic (N)
	Riven Slate Natural Finish (N)
	Natural Stone (N)

* High (R_z value below 10); Moderate (R_z between 10 to 20); Low (R_z above 20)

Besides that, a research was done to analyze effect of the frictional response of contacting surface in boundary lubrication by lubrication and define its texture. As the result, the dry disk showed the greater change in S_a and S_q followed by base lubricated disk and disk which lubricated with nano lubricant had the least amount of change in S_a and S_q. [12]

Effect of machining feed on surface roughness in aluminum was studied. The study was done to reduce automotive component manufacture cycle time in order to achieve surface roughness specification. Reduction of feed rate will lead to improved surface quality of machined surface. In general, higher surface roughness at entry/exit point compared to middle point of the specimen. This was due to disturbances/vibration induces when cutter enters/exits the specimen. [13]

Roughness of a texture tuned and modified the surface properties of the material such as wettability. Roughness enhanced the hydrophilicity of the material and affect the apparent angle and increase solid energies. [14, 15] Surface roughness also had strong influences on the attachment ability of the insect and a study showed that performance of insect on smooth surface was stronger than that with micro-roughness. [15]

In aspect of the food nanoscience and nanotechnology, the micromechanical properties of hen's egg were studied. Surface roughness of the hen's egg was evaluated and Ra values were observed as 6.54±0.45nm. [16] A research stated that eggshell roughness enhanced embryo survival during nest inundation. Surface "roughness" entrapped the air bubble at the eggshell surface and allowed for gas exchange through the eggshell. [17]

Turbulent flow on the heat transfer surfaces was affected by the surface roughness even when the surfaces were carefully prepared. The effect of the surface roughness depended on the ratio of the height of roughness to hydraulic diameter. The roughness elements were not in same size or in equally distribution and the roughness was expressed in term of a relative roughness ratio. [18]

In the aspect of manufacturing techniques of tropical natural fiber composites, the hand lay-up process was used to manufacture the telephone stand from the banana pseudo-stem fiber reinforced unsaturated polyester composite. It produced the product with excellent surface finish but it was only on single surface. [19]

In the aspect of topology of natural textures, natural rubber specimens were done on a research to be subjected to tear, flexing, fatigue, abrasion and tensile tests. Digital image processing was used to perform quantitative statistical and spectral texture analysis. In this research, at under-cured state, the fracture surface of Sulphur-cured natural rubber was with tear paths which was less than for the Sulphur-cured natural rubber at optimum cross-linked state on their smooth surface. Stick-slip type of tear propagation showed on tear texture surface of peroxide-cured natural rubber at under-cured state. Meanwhile, the digital image of tear surface of Sulphur-cured natural rubber (carbon filled) system was coarse and had occasional formation of short tear lines. At optimum cross-linked state, micro folds are showed along with stick-slip tearing on the fracture surface and number of short tear lines was greater on the tear surfaces of the

Sulphur-cured natural rubber (carbon-filled) system compared to those surfaces at under-cured state. Tear fracture surface was coarse in fracture for Sulphur-cured natural rubber at excess cured state. Meanwhile, few parabolic tear lines showed on the tear surface of peroxide cured natural rubber at excess cured state. The digital image showed the highest value of entropy for optimally cross-linked Sulphur-cured natural rubber at elevated temperature of 150˚C. Entropy was a measure of randomness and the digital image showed the presence of non-uniform surface and thick tear lines on the tear surface of peroxide cured natural rubber at optimum cross-linked state and elevated temperature of 150˚C. Thick tear paths and mud cracks were transformed from short tear lines on the tear surface of Sulphur-cured natural rubber (carbon filled) system at optimum cross-linked state and elevated temperature of 150˚C. [20]

The description of food surfaces and microstructural changes was done on a research. Roughness of the surfaces became obvious in visual when fractal dimension (FD) values was more than 2.30. The study showed that the surface intensity (SI) map of the pumpkin was more jagged compared to the chocolate and it indicates a wider range of pixel intensities although surface image of the pumpkin was much rougher than of chocolate to the naked eye. FD value for pumpkin was higher than for chocolates when describing the differences between the surface texture. Besides that, the topology of the surface of the rough and smooth sandpapers were studied in this research. The abrasive particle appeared on the rough sandpaper as white spots of larger size. FD was increasing when the roughness was increasing and it described the large variation in visual and sensorial texture. [21]

Besides that, the porcelain surface texture after reduction using different abrasive techniques and after undergoing nature glazing were studied in a research. The new diamond stone produced the roughest surface of porcelain compared to used diamond stone. The carbide stone and Shofu white stone caused equal minor degree on the porcelain surface. Sandpaper produced the minimal roughness on the porcelain surface and the original porcelain surface which was not undergo any reduction using abrasive techniques and glazing were not completely smooth. The degree of roughness was the roughest for the glazed porcelain surface after subjecting to new diamond stone followed by used stone, Shofu stone, carbide stone and lastly sandpaper. This research also studied that the glazed porcelain surface had least amount of surface roughness after sandblasting with aluminum oxide powder and reduction using abrasive technique. [22]

The influence of the surface roughness and tip geometry on the adhesion force mapping on wood was studied on a research. Rough surface resulted in more complete wetting behavior compared to smooth surface when testing different textures of the natural surfaces. Macrofibrils of the inner all surface formed a characteristic vary texture. In this study, the cut cell wall surface of early wood was generally rougher than late wood region. For the direction parallel to the cut surface, the roughness of the fiber was lower compared to those in the direction less parallel to the cut surface. [23]

Besides that, hydrophobicity was induced by the surface texturing. The magnolia leaf, Colocasia esculenta leaf and lotus leaf were used as case study. The surface of magnolia leaf had a needle-like microstructure with spherical top. Meanwhile, Colocasia esculenta leaf surface had micro bumps with nano hair. Lotus leaf surface consisted of micro protrusions which functioned to support the water droplets and prevent the droplets to get punctured and had nano hair. [24]

Some surface properties such as color, surface roughness and glossiness of heat treated and natural weathered Oriental beech were investigated in a research. Heat treated wood decreased in lighting and became darker and resulted in better surface roughness and glossiness when it was compared to non-heated after natural weathering. Besides that, lighter the color of heat treated wood after natural weathering was whereas the color of non-heated wood became darker. As the result of this research, better surface characteristic of Oriental beech after natural weathering was due to higher temperature and duration of treatment. [25]

The surface roughness of hydrogels by Fractal Texture Analysis before and after swelling poly (2-hydroxyethyl methacrylate) [pHEMA] was evaluated. Surface of the dry polymer showed stripes presented on the mold and disappeared progressively along the hydration process. Dry polymer was formed due to the interaction of the ionizable groups of its macromolecular chains with the ionic species in the solvent which resulted in an expansion of the network. Progression of water led to the chain relaxation and a decrease in surface roughness. [26]

The properties of limestone were studied in order to investigate the role of climate and air pollution on the characteristic and morphology of weathering crusts on the porous limestone. Based on the X-Ray Diffraction (XRD) analyses, 92-97% of calcite and a small amount of quartz and sand-sized lithic clasts were found in limestone. The differences in the surface texture of fine grained limestone and medium grained limestone were pointed out. Very small ooids were presented in diameter of 0.1 to

0.2mm on the surface of the fine grained limestone and high effective porosity about 37% which was higher than that of medium grained limestone because most of the pores were intergranular whereas coarser ooids, rounded calcite ooids and micro-oncoids were found in medium grained limestone and the pore sizes was around 0.01 to 0.02mm. [27]

Geological considerations of rock texture were discussed in order to describe the fractal description of rough surfaces for haptic display. There were three types of textures discussed in this research, which were aphanitic textures, porphyritic textures and phaneritic textures. The first one was due to having barely/not visible grains/crystals of rocks. Meanwhile, the second one was occurred due to visible grains of rocks surrounded by an aphanitic matrix whereas the third one was due to slowly cool underground of the rocks. Glassy texture was formed on the surface of a volcanic rock after undergoing a rapid cooling. Texture gave impact in geology on the formation and classification of the rocks because it involved in cooling time and cooling mechanism on the formation of rocks. [28]

Micro textures of natural coke from seam XIV, Jharia coalfield, India were exposed through the help of optical microscope techniques and Scanning Electron Microscopy (SEM). Some of the features of coke were studied such as shape and size of cracks, fissures and micro pores and unaltered and altered coal fragments/remnants. As the further exploration, the greater details on the size and shape of mesophase spheres, mosaics, flow textures and deposited carbon will be studied. [29]

Hydrogen induced cracking (HIC) in oil and natural gas pipeline steel was focused in order to investigate behaviour of hydrogen induced cracking (HIC) on the API X70 pipeline steel. Based on the SEM result, center of the cross-section of pipeline steel where center segregation of elements had occurred had higher concentration of inclusions and precipitates such as manganese sulphide and carbon nitride precipitates compared to the other areas. [30]

Instant controlled pressure drop process (ICPD) was a pre-treatment for the textures in order to enhance efficiency of phenolic compounds on the metal but it led to higher porosity on the metal surface compared to the untreated one. [31]

Fissure was less caused by the superheated stream (SS) to lightly milled rice (LMR) than that caused by Hot Air (HA) whereas the untreated LMR showed no fissure on kernels. The morphological characteristic of transverse section of LMR kernels were changed by undergoing the HA processing whereas there was no change in morphological characteristic for SS processing as it was flat as the untreated one. Meanwhile, the topologies of cooked SS were similar to that of untreated cooked one whereby there was irreversible loss of shape for cooked HA due to serious deformities altered texture profile. [32]

A research was done to investigate the geometrical and physical properties of filler in filler –bitumen. It summarized the shapes and textures and some description of SEM imaging of surface of the hydraulic lime (H), hydrated lime (HL), Portland cement (PC), Limestone filler (LF), Basaltic filler (BF) as shown in Table 2.2. [33]

Table 2.2: Summary of the shapes and textures and descriptions of SEM imaging of surface of the hydraulic lime (H), hydrated lime (HL) , Portland cement (PC), Limestone filler (LF), Basaltic filler (BF) [33]

Type of filler	Shape*	Texture	Description
H	Granulous	Rough	Granulous type of particle with very rough surface
HL	Granulous	Very Rough	Largest particles (63µm), an agglomeration of particle
PC	Angular	Smooth to slightly rough	Not show same affinity to form agglomerations
LF	Angular and Granulous	Smooth to rough	Angular type particles with smooth to rough texture
BF	Angular, Granulous and Spherical	Smooth (angular and spherical), slightly rough	Other shape type of particles which resulted from contamination with other aggregate sources.

*Granulous (Irregular Isometric); Angular (With sharp corners)

Comparison of bio-based compound processing and composites reinforced with short glass fibres (GF) was described to provide a quantitative overview. As the result, fibre surfaces of cellulose was different significantly from that of abaca. A significantly large fibre diameter of abaca fibre was scattered through a fibre yarn drastically and it was scattered even along single fibre bundle. Mechanical anchoring of polymer melt was affected by rough surface and it led to a better impregnation and improved adhesion. Meanwhile, the man-made cellulose had very fine fibre structure with its constant diameter and formed a smooth surface. [34]

In aspect of food nanoscience and nanotechnology, pre-existing cracks and crack deflection were showed in the optical image of a residual footprint indentation on hen's egg. [16] Besides that, the same overall structures were observed when comparing the eggshell structure of the guinea fowl and greylag goose but there was different in relative thickness of layers in these two taxa. In comparison of composition of these two types of eggshells, both eggshells were made of calcite but the organic component was different in these two types of eggshells in the aspect of quality and quantity. [35] Other than that, a research was done to study on the effect of the cooking on avian eggshell microstructure. As the findings, no significant different was found when comparing boiled 3 minutes, boiled 12 minutes and baked eggshells which irregular sized and spaced mammillae was well defined in all these samples. But varying degree of damage was observed in fire-cooked eggshell and it was due to delamination of the mammillary cone layer. [36]

Besides that, microstructure of uncarbonized and carbonized eggshell particles were observed to reveal that size and shape of the particles and they consisted of porous irregular shaped particles. Besides that, Calcium (Ca), Silicon (Si), Oxygen (O), Magnesium (Mg) and Phosphorus (P) were found as the composition of both carbonized and uncarbonized eggshell particles, however the presence of carbon was found in carbonized eggshells and carbonized eggshell consisted of carbon in graphite form. [37]

The micrographs of high-density polyethylene (HDPE) composites with 10% by the weight of banana fibre (Fint) pure or impregnated were observed in order to compare with that with banana fibers (Finterm and Fext) pure and impregnated. As the result, there were no different between high-density polyethylene (HDPE) composites with 10% by the weight of banana fibre (Fint) and that with banana fibers (Finterm and Fext) pure and impregnated but it was observed that the surface roughness of the composites with the treated banana fibers were higher compared to the untreated one. [38]

The banana leaf and coconut coir had the highest relative ratios by mass for carbon whereas the banana stem and coconut sheath had the highest relative ratios by mass for oxygen. Optical images of sugar cane bagasse fiber and banana trunk fiber were observed to study on the effect of different treatment in influencing morphological properties. A decrease in the amount of extractive content was exhibited in pyrolysis treatments because it involved the elimination of the methanol and acetic acid and contributed to an increase in surface roughness from raw fiber state. Alkali treatment had affected lignin and extractive content which caused the total fiber mass decreases. After undergoing alkali treatments, damaged fiber skeleton was observed because alkali treatment tended to disrupt the cell wall of the fiber and dissolve the matrices of wood materials that consisted of hemicellulose and lignin but this situation was not happened on the banana trunk fiber and it showed a constant amount of hemicellulose. In the case of acid treatments, cellulose content was increased but the hemicellulose content was decreased due to dissolution of hemicellulose and cellulose caused by sulfuric acid. Partly damaged skeleton of fiber and its surrounding layer were observed on the acid treated fiber. [39] Characteristic and composition of banana fiber were introduced in a research about variability and fracture behavior of banana fiber. Banana fiber was basically lignocellulosic and amorphous matrix of lignin and hemicellulose consisted of helically wound cellulose microfibrils. The composition of banana fiber was observed by its percentage using elemental analysis as shown in Table 2.3. [40]

Table 2.3: Composition of banana fiber [40]

Constituents	**Percentage (%)**
Cellulose	31.27±3.61
Hemicellulose	14.98±2.03
Lignin	15.07±0.66
Extractives	4.46±0.11
Moisture	9.74±1.42
Ashes	8.65±0.10

In the aspect of techniques used for surface roughness measurement, there were some issues arise if using stylus instruments. One of the issues was height relation range need to be concerned. The height resolution and range was set depend on two factors which were transducer and mechanical noise and straightness of transverse mechanism. The first one was based on the optical interferometry and it produced a signal which was directly proportional to height. Inductive and Piezoelectric transducers were preferred to use as they were sensitive to the vertical motion of the stylus and they were generally used in industrial shops. Three designs to achieve low scanning noise and good straightness of travel were recommended which were use of skid which was the least expensive method, external datum surface as guide line on the surface very near to the linear variable differential transformer (LVDT) and the last one was to provide highly noise-free motion but the degree of flexure bent limited the trace length as the elastic bending forces became too large. Besides that, bandwidth limits for surface metrology and stylus load and surface deformation needed to be concerned. [41] For stylus measurement, needle board profilometer was used to describe the surface roughness of soil surface. It was able to obtain the overview of effect of tillage to the toil surface but the needle of profilometer laid in the disturbance of soil surface. [7]

A method that was developed to predict the surface roughness 3D parameters which will give more precise image of surface. Important of development of this technique was it will be more reliable, precise, low-cost and non-destructive. [42]

If dealing with working surfaces which have surface roughness with standard deviations under 10nm, surface roughness measurement in nanometer scale were used. In order to achieve nanometer scale roughness measurement, there were some problem needed to be concerned. One of the problems that had been pointed out was when distance between asperities was less than 0.1 to 1μm, poor lateral resolution occurred and led to limited application of optical instruments to the nanometer. Besides that, using scanning tunneling microscope (STM) and atomic force microscope (AFM) encountered problem of determine average dimension of topological element which formed the surface of solid at the molecular level, had difficulty to compare surface in order to investigate the impact of fine roughness during friction and to model contact. Furthermore, the available instrument had a problem to accumulate data by the maximum possible topological resolution. [43]

The texture analysis approaches were categorized into 4 groups which are structural, statistical, model based and transform methods. The first one was using well-defined primitives and a hierarchy of spatial arrangement of those primitives in order to represent texture. [44, 45] The disadvantage of this category of texture analysis was it was only suitable for certain application where there were very regular textures. [44] The second one was non-deterministic properties that governed the distribution and relationships between grey levels of an image to represent the texture indirectly. [44, 45] Difficulty of this type approach was pointed out that implementing this approach to be measurement variant, measurement inconsistencies because roughness for one application was waviness for the another, which indicated that roughness was an application dependent. [28] The third one was interpreting an image texture by using fractal and stochastic model whereas the fourth one was using coordinate system that had on interpretation that was closely to the texture characteristic in order to describe an image in space. [44, 45]

A regular light microscope was used to count the number of pores per square millimeter in each eggshell and thickness of each eggshell in millimeter was measured using an eyepiece graticule in a light microscope. [36, 46] Scanning Electron Microscope (SEM) was used to the qualitative description on the eggshell surface [36] and was great potential tool to characterize the heat transfer surface. [18]

Chapter 3 Methodology

3.1 Samples Preparation

3.1.1 Eggshell Samples Preparation

Quail eggs, duck eggs and chicken eggs were bought from the convenience store and were firstly boiled and the shells were broken. After that, the eggshells were peeled off into 20 small pieces of sample. Then, the eggshells were rinsed under tap water and cleaned with detergent mixed with hot water for 1 minute for removing oil on the eggshells' surface. Lastly, the eggshell samples were rinsed with tap water and air dried at room temperature for several days in drying agent container prior to usage.

3.1.2 Banana Inner Trunk Samples Preparation

Banana trunks were cut from the banana plant. The banana inner trunks were peeled off from the banana inner trunk. The banana inner trunks were classified according to the maturity of the banana inner trunk. 20 small pieces of sample were cut from the banana inner trunk and air dried at the room temperature for several days in drying agent container prior to usage.

The silica gels were placed in the sample container to keep off the moisture in the dried sample as shown in Figure 3.1. The banana trunks samples were classified according to their maturity stages.

Figure 3.1 Banana Inner Trunk at growth stage with silica gel

3.2 Surface Roughness Measurement

Surface roughness of inner and outer surfaces of eggshell samples and banana inner trunk samples were measured using surface profilometer ZEISS SURFCOM 130A as shown in Figure 3.2. The dimension of each eggshells and banana inner trunks used for roughness measurement was about 2 cm length and 2 cm width. The distance travelled by the stylus of surface profilometer was marked on the inner and outer surfaces of eggshell samples and banana inner trunk samples. The surface profile of inner and outer surfaces of eggshell samples and banana inner trunk samples shown by the surface profilometer were printed out using carbon-printed papers and the roughness values, R_a and R_q were tabulated for each inner and outer eggshells surface respectively and were plotted in the graph for further analysis.

Figure 3.2: Surface profilometer ZEISS SURFCOM 130

SOLIDWORKS is used to illustrate the surface roughness measurement method for eggshells and banana inner trunks samples in both lateral and longitudinal directions.

Table 3.1 shows the parameter used in surface roughness measurement using surface profilometer ZEISS SURFCOM 130A. Evaluation length was the distance set to be travelled by the stylus of the surface profilometer. In this reaserch, the evaluation length for all the surface roughness measurements in each diversity of eggshells and banana inner trunks at different maturity stages was set as 2.000mm but it was set as 1.000mm for surface roughness measurement of inner surface of banana inner trunks at different maturity stages in lateral direction. Measurement speed (M. Speed) was speed used to travel along the sample to collect data for surface roughness values. 0.33mm/s was set to be used in this research. Cutoff value depends on the measurement speed. 0.8mm was used as cutoff value in this research. Gaussian was used as type of filter for roughness and waviness measurement. Taking measurements by setting measurement range (Meas. Range) within ±400µm. 400µm was set for the upper and lower boundaries of the level meter. Straight was a type of tilt correction to be performed according to the data obtained after measurement used in this research. There was no short wave filter (C.F.R.) used for roughness measurement. For creating the roughness profile, the Vertical Magnification (V-Mag), Horizontal Magnification (H-Mag), Vertical Division (V-Div.) and Horizontal Division (H-Div.) were set to be automatic which indicated that they changed according to the roughness data collected. [47]

Table 3.1: Parameter Used in Surface Roughness Measurement Using Surface Profilometer ZEISS SURFCOM 130A

Parameter Used	Details
Evaluation Length(mm)	2.000 (For all the surface roughness measurements in each diversity of eggshells and banana inner trunks at different maturity stages **EXCEPT** surface roughness measurement of inner surface of banana inner trunks in lateral direction)
	1.000 (Surface roughness measurement of inner surface of banana inner trunk at different maturity stages in lateral direction)
Measurement Speed(M. Speed)(mm/s)	0.3
Cut-off value(mm)	0.8
Cut-off	Gaussian
Measurement Range (Meas. Range)(µm)	±400.0µm
Tilt	Straight
C.F.R.	None
Roughness Profile • Vertical Magnification (V-Mag)	Auto
• Horizontal Magnification (H-Mag)	Auto