An Overview of Okra Fibre Reinforced Polymer Composites

Nadendla Srinivasababu
Department of Mechanical Engineering, Vignan's Lara Institute of Technology and Science, Vadlamudi–522 213, Andhra Pradesh, India.

E-mail: cnjlms22@yahoo.co.in

Abstract. Increasing attention towards “sustainable environment” invited the development of new materials to satisfy the needs of the public with less/no damage on surroundings. In this regard a specific attempt is made by the author to do review and understand the performance of the variable vegetable fibres of okra which is botanically called ‘Abelmoschus Esculentus’ and their composites under various conditions of load. Further the results exist in the literature are also reviewed for the purpose of comparison.

1. Introduction
Natural fibres may be classified based on the origin i.e. plant, animals or minerals of birth. A typical bio fibre consists of (i) helically arranged crystalline micro fibrils of cellulose, (ii) amorphous region mainly consists of lignin and hemicellulose, (iii) disorderly arranged crystalline cellulose micro-fibrils network, (iv) primary wall, (v) secondary wall S1, (vi) secondary wall S2, (vii) secondary wall S3, (viii) Lumen. The overall properties of the fibre will dependent on the property of each constituent whereas the reinforcing ability of the natural fibre is dependent on the nature of cellulose and its crystallinity. Cellulose fibrils are aligned along the length of the fibre which renders maximum tensile, flexural strengths along with rigidity [1].

In order to achieve strong interfacial adhesion an intimate molecular contact at the fiber-matrix is required. Based on adhesion characteristics an interface can be classified as follows [2].

1. Sharp interface with weak molecular force, as in the case of non-polar polymer with a polymer fibre: in such a case the interface will be mechanically weak because of lack of chemical affinity and wettability leading to interfacial slippage.

2. Sharp interface with strong intermolecular, such as the dispersion force between a non-polar polymer and a high energy material or intermolecular forces involving specific interactions i.e. primary or secondary. In this case interface slippage will not occur and the interface will be mechanically strong.

3. Diffuse interface with any intermolecular: when there is sufficient molecular diffusion, entanglement and, and/or anchoring sites, interfacial slippage will not occur. Therefore both primary chemical bonds and secondary bonds are important to attain adhesion depending on interfacial structure.

1 Corresponding Author Address: Dr. Nadendla Srinivasababu, Professor & Head, Department of Mechanical Engineering, Vignan’s Lara Institute of Technology and Science, Vadlamudi – 522 213. Andhra Pradesh, India. E-mail: cnjlms22@yahoo.co.in, Ph: 0863– 2118507, Fax: 0863-2118456.
The researchers have struggled in order to reinforce variety of natural fibres (as is condition or modified physically/chemically) into diversified matrices to achieve target properties. In this paper an attempt is made to do review on the mechanical and dielectric performance of okra fibre (Individual form and Oval chain structured form) reinforced polyester composites at various fibre contents. Further analysis is carried out by to compare the results with the values exist in the literature.

2. Fibre, Matrix and Composites Manufacturing
The present section describes fibres, matrices used for the fabrication of the composites and the testing procedures adopted.

2.1. Fibre
Okra is botanically called Abelmoschus Esculentus and this crop is extensively cultivated in few parts of the India. An attempt was made by Nadendla srinivasababu in the year 2007 to manufacture the composites reinforced with okra individual fibres of Srikakulam origin and the results were published elsewhere [3]. Then he extracted the good and fine okra fibre in 2008 from the crop grown in the village of Gorigapudi, Bhattiprolu Mandalum in the state of Andhra Pradesh, India. The crop is very neatly grown because the seeds (2405133 variety) are purchased from Syngenta Ltd., Shivaji Nagar, Pune, India. Another variety of okra fibre was extracted from the crop grown from the seeds of Indra–32 variety purchased from Prabhakar Seeds, Gandhi Nagar, Bangalore, India. The two varieties of the fibre are extracted by “Retting and Manual Extraction Method”. Hybrid okra variety (2405133) exhibited two kinds of fibres i.e. (i) Fibres are in individual form/filaments; (ii) Fibres are in Oval Chain Structured Layered forms and are shown in Figure 1, 2 respectively.

![Figure 1](image1.png)  
**Figure 1** Extracted Okra hybrid Variety 2405133 individual fibre

![Figure 2](image2.png)  
**Figure 2** Extracted Okra hybrid Variety 2405133 oval chain structured fibre in layers
Now the focus is made on other okra fibres reported by the authors available in the literature. Okra Bast Fibre (OBF) was collected from Jhenaidah regions in Bangladesh. In order to remove the dirty substances, OBF was scoured in a solution containing 5 mg Na$_2$CO$_3$ and 5 gm detergent per liter of water at 70 °C in a large beaker [4]. Here also the authors collected okra plants from the same region and were retted into water for 13 – 15 days and the fibre was collected [5]. Retting time to extract the okra fibre was 20 days [6]. The plant had been collected from in Kushtia District (Bangladesh) and was kept under water (15 – 20 days) to allow microbial degradation and the extracted fibre was washed with deionised water [7, 8, 9, 10 and 11].

2.2. Matrix and Method of Manufacturing

An Ecmalon 4413 Unstaurated polyester resin was used to fabricate the OIFV–1, OIFV–2, OOCSFV–1 and OOCSFV–2 composites by wet lay-up technique i.e. according to the regular procedure. In hand lay-up technique the fibre is placed, the resin is poured in the mold as per the predetermined proportions and is allowed to cure for 24 h.

Cut okra fibres 2 – 3 mm size was reinforced into bakalite by hand lay-up technique and tried the possible dispersion during the preparation of the composites [7]. Poly(lactic) acid was used as a matrix to fabricate composites by injection molding [11]. In injection molding technique the predetermined quantity of fibre is blended thoroughly with matrix and is processed as per the normal procedure for making the composites.

2.3. Chemical Treatment

Various chemicals and treatment procedures were adopted in order to improve the mechanical behavior of the composites by enhancing their bonding i.e. reinforcement and matrix. The details of the chemical treatments followed by the author and the procedures adopted in the literature are given in Table 1. The author has also made a specific effort to manufacture the composites reinforced with the fibres which were treated under accelerated environmental conditions i.e. affect of acid rain. The author has considered the acid rain condition because the environment is exposed to gigantic pollutants, hence it is essential to understand this affect on degradable materials i.e. fibre and its composites.

| Fibre | Form                        | Treatment                  | Procedure (Concentration, Soaking time) | Reference |
|-------|-----------------------------|----------------------------|----------------------------------------|-----------|
| OIFV–1 CT–1 Individual long | NaOH, KMnO$_4$, H$_2$SO$_4$ | 0.125 M – 6h, 0.03164 – 14, 1.87602×10$^{-5}$ | Corresponding authors study |
| OIFV–1 CT–2 Individual long | NaOH, KMnO$_4$, H$_2$SO$_4$ | 0.125 M – 45 min, 3.752×10$^{-6}$ – 5 min | " |
| OIFV–1 CT–3 Individual long | NaOH | 0.1875 M – 1 h | " |
| OIFV–2 CT–1 Individual long | NaOH, KMnO$_4$, H$_2$SO$_4$ | 0.25 M – 5h 55 min, 0.01266 – 2 min, 3.752×10$^{-6}$ – 2 min | " |
| OIFV–2 CT–2 Individual long | NaOH, KMnO$_4$, H$_2$SO$_4$ | 0.125 M – 6h, 0.03164 – 14, 1.87602×10$^{-5}$ – 14 min | " |
| OOCSFV–1 CT–1 Oval Chain structured layered | NaOH, KMnO$_4$, H$_2$SO$_4$ | 0.125 M – 45 min | " |
| OOCSFV–1 CT–2 Oval Chain structured layered | NaOH, KMnO$_4$ | 0.125 M – 45 min, 0.006328 – 5 min | " |
| Process | Stage | Description |
|---------|-------|-------------|
| OOCFV-1 | CT-3  | Oval Chain structured layered NaOH 0.1875 M – 1 h |
| OOCFV-2 | CT-1  | Solution (3.5 gm Na₂CO₃ and 6.5 gm detergent per litre of water) 60 °C – 30 min |
| OBF    | Individual | Ratio of fibre-to-solution 1:50 |
|        | Bleaching | Digesting the scoured fibre with 0.7 % sodium chlorite solution buffered at pH 4–2 h 90 – 95 °C Stating – 30 °C increased up to 90 °C – 30 min Reaction continued for 210 min. |
| Okra   | 50 cm length | Bleached 10 % NaOH + 10 % Na₂SO₄ at 30 °C |
| Okra   | Individual | SOF Scouring with a solution of 3.2 % sodium carbonate and 6.3 % soap flake |
|        | AAROF   | Acetylation with 10 % acetic acid |
|        | AABOF   | Bleaching with 10 % sodium chlorite |
|        | BOF     | Bleaching with 10 % sodium chlorite Treatment with 1 % sulphuric acid followed by 0.055 % potassium permanganate |
|        | SAKPOF  | Treatment with 10 % sodium dodecyl sulphate |
|        | SSROF   | Bleaching with 10 % sodium chlorite followed by 1 % sodium hydroxide alkalisation |
|        | SHBOF   | |
| Okra   | Chopped 5-10 mm | Boiling mixture in toluene/ethanol 6 h |
3. Test, Results and Discussion
The present section describes fibres, matrices used for the fabrication of the composites and the testing procedures adopted along with the procedures adopted in literature. Then a specific care is taken to understand the physical, mechanical properties of the fibre and its composites which were tested under tensile, flexural and impact load at different levels of fibre reinforcement. The author has done the manual modification of the existing fibre to form as a woven fibre and experimentation on okra woven FRP composites and the results were published elsewhere.

3.1. Physical and tensile properties of fibre
The chemical composition of the okra bast multicellular fibre was determined. The values reported by Md. Shamsul Alam et al. are \[ \% \] 
- 67.5 % \( \alpha \)-cellulose, 
- 15.4 % hemicellulos, 
- 7.1 % lignin, 
- 3.4 % pectin matter, 
- 3.9 % fatty and waxy matter and 
- 2.7 % aqueous extract.

The density of the okra fibre was determined by ASTM D 3800-99 and its average value is 881, 817 kg/m\(^3\) for OIFV-1, OOCSF-1 respectively.

Initially the fibre was tensile tested on Electronic Tensometer and its tensile strength, modulus were calculated. Out of all the fibres investigated in the present work OIF V1 CT-2 had shown highest tensile strength, modulus of 151.46 Mpa, 2.66 GPa respectively. In case of OOCSFV-1 CT-3, CT-1 fibre had exhibited more tensile strength (36.19 Mpa), modulus (1.85 Gpa) respectively. One may understand that the chemical treatment was responsible for the enhancement in bonding between the fibre and matrix. Tensile strength, modulus of untreated and treated OI, OOCSFV1, 2 against percentage strain of all the tested samples is graphically shown in Figure 3 a, b, c and d. Out of raw, bleached, alkali treated, AN-grafted 7.38%, 11.43% okra bast fibres investigated, grafting of bleached fibre with acrylonitrile brought a substantial increase in tensile stress and its value is nearly 80 N/mm \[ 6 \].

Figure 3. Tensile strength, modulus of okra individual, oval chain structured fibre
The tensile strength, modulus were decreased with increase in diameter of okra fibre. Khustia Dt. Okra fibres (more than eighty) were tested (10 mm gauge length) according to ASTM D 3379-75 on Lloyd Dynamometer LR30K with 20N load cell at a crosshead speed of 1mm/min [8]. The mechanical properties of okra fibre (raw and treated forms) were reported by I. M. De Rosa et al. [9]. The tensile strength, modulus of okra fibres had shown variability with respect to diameter and their values were in the following range: diameter 88.3 – 218.9 µm, tensile strength 52.6 – 233.8 MPa and modulus 3.2 – 12.8 GPa [9].

3.2. Scanning Electron Micrograph Analysis of fibre
The surface morphology of the OIFV-1, 2 treated and untreated fibres were shown elsewhere in the paper published by corresponding author. Now the SEM images of untreated and treated OOCSF fibres are given below along with the individual fibres for comparison, Figure 4–13.

![Figure 4. SEM image of OOCSFV-1](image1)

![Figure 5. SEM image of OOCSFV-1 CT-1](image2)

![Figure 6. SEM image of OOCSFV-1 CT-2](image3)

![Figure 7. SEM image of OOCSFV-1 CT-3](image4)
Okra oval chain structured fibre with channels and other matters are visible from Figure 4 whereas a clear flattened rough surface obtained after CT-1 is observed from Figure 5. The composition CT-2 resulted in much rougher surface with loss of fibrils is noticed from Figure 6 whereas alkali treatment resulted in the exploiting of neat cylindrical filaments, Figure 7. The flat filaments bonded together are understood from Figure 8. Very fine filaments are visualised from Figure 9 in case of OIFV1. Some of the useful cellulosic materials lost in CT-1 of OIFV1 and was resulted in channel formation, Figure 10.
The formation of near square boxes on circumference of fibre surface is due to the CT-2 on OI FV1, Figure 11. The Figure 12, 13 represents the formation of filaments and deteriorated surfaces respectively. A considerable amount of polyacrylonitrile was grafted onto okra bast fibre surface and intercellular gaps were also reduced due to the decomposition of PAN grafts which was identified when bleached and AN-grafted okra bast fibre micrographs were observed [5]. When raw, bleached and alkali treated okra fibres were observed at different magnifications the multicellular nature of okra fibre is more clearly visualized [6]. The presence of reasonable number of voids along okra fibre length was observed. The non selective nature of treatment on okra fibre resulted in increase of voids in the fibre and was also observed in the image [7].

The cross section, longitudinal surface of okra fibre was microscopically examined by I. M. De Rosa et al [8]. The structure of an okra fibre consists of several elementary fibres or ultimate fibres or cells overlapped along the length of the fibres and bonded firmly together by pectin and other non cellulosic compounds. The region at the interface of the two cells is called middle lamella and the bundles of elementary fibres are referred to as technical or single fibres. They have also observed a polygon shape that varies from irregular to circular. Brittle behaviour with the absence of significant fibril splitting along with the fibre pull-out in the outer part of the bundle was observed. The presence of cell wall defects along the fibre length may create stress intensities and were responsible for different fibre cells fractured at various stress levels [8].

I. M. De Rosa et al. [9] have used SEM micrographs to measure cross sectional area of fibre more accurately and the results were used to recalculate the mechanical properties. Fracture surfaces present a variable level of twisting as an effect of chemical modification. Chemical modification resulted in variable level of twisting and was observed on fracture surfaces. The surface both along the length and in section appear smoother in case of acetylated and bleached okra fibre, which may be ascribed to the regeneration effect of the fibres due to acetylation. The presence of small holes around the mid section of the fibre(s) was observed due to permanganate treatment on okra fibres which may be ascribed to some degradation of the structural part of the fibre owed to the treatment.

The increase in porosity with 90.02% permanganate treatment in alkaline solution has also been observed in sisal fibre [9]. E. Fortunati et al. have described that the dimensions of unmodified okra fibre is in the order of 90 µm. Chemical treatment (dewaxing, bleaching, and alkali treatment) of fibre split the fibres and increased their surface area [10]. Pristine okra fibres (untreated) had shown polygonal shape with a diameter of 88.3 µm (which was calculated in a series of fifty fibres). After chemical treatment the fibre diameter was 9.8 µm. The morphology of the okra derived cellulose lateral surface shows a quite rough surface, and is oriented in the longitudinal direction [11].

3.3. Tensile Properties of Composites

The specific tensile strength and modulus of the composites was determined and is shown in Figure 14, 15. The composites reinforced with OI FV1 CT-2 fibre have exhibited highest specific tensile strength (60.75 Mpa/kg.m$^3$×10$^{-3}$), modulus (978.75 MPa/kg.m$^3$×10$^3$) than all other okra fibre reinforced polyester composites investigated by Nadendla Srinivasababu. Under the composites reinforced with okra oval chain structured fibres in layered form CT-2 to the fibre resulted in good interfacial bonding between fibre and matrix which is evidenced from the experimental results i.e. specific tensile strength of 56.83 MPa/kg.m$^3$×10$^3$ and modulus of 834.99 MPa/kg.m$^3$×10$^3$ was observed at maximum (27.85 %) fibre volume fraction. All the composites were failed due to tensile load only and no fibre was pulled out from the matrix.

Lady finger fibre (untreated, bleached) reinforced Bakelite composites had shown decrease in tensile strength with increase in fibre content. The maximum value achieved in case of untreated, bleached fibre composites was nearly 18.2, 16.5 MPa respectively at its lowest fibre content [7]. E. Fortunati et al. [10] reported that PVA/10CNC composites have showed the highest value of elastic modulus of 1.9 GPa.
3.4. Flexural Properties of Composites

The specific flexural strength and modulus of the composites (reinforced with OOCS, OI fibre) against fibre volume fraction is graphically represented in Figure 16, 17 respectively. All the okra fibre reinforced polyester composites (except OI FV1) have shown increasing trend of flexural strength with increase in fibre volume fraction. In these composites the composites reinforced with individual fibres at 35.05 %, 31.21 % fibre volume fraction have shown highest flexural strength, modulus of 108.7 MPa/kg.m$^{-3}$ and 9.52 MPa/kg.m$^{-3}$. Very good interfacial locking is shown by the OOCS FV2 CT-1 FRP composites and its flexural modulus was 5.39 MPa/kg.m$^{-3}$, which was highest in okra oval chain structured fibre reinforced polyester composites. All the composites were failed due to bending only and failed in its outer most layers, which is highly desired.
3.5. Impact Properties of Composites
OI FV1 FRP composites with 12.7 mm width have exhibited impact strength of 52.45 kJ/m$^2$ which is higher than all other OI and OOCS fibre composites investigated. OI, OOCS FV1 reinforced polyester composites had shown increase in impact strength with fibre content. The okra FRP composites with 10 mm width specimens have shown an increase in impact strength with increase in fibre volume content which is recognizable from Figure 18. All the composite specimens had shown clear break of the specimens and is designated as ‘C’ as per ASTM D 6110 – 08.

3.6. Dielectric properties
The insulation property of the composites is assessed for okra individual fibre reinforced polyester composites. The dielectric strength of the composites is determined and is shown against fibre volume fraction, Figure 19. The highest value of dielectric strength (9.67 kV/mm) is achieved at 6.59% fibre volume fraction. Hence the designer will get an opportunity to select the light weight insulating materials based on the data available.
3.7. Environmental Impact Assessment

In order to understand the present section one has an idea of conditions of formation of acid rain. The pure rain water possesses a pH of about 5.6 and is acidic due to the equilibrium established between water and carbon dioxide in the atmosphere which is resulted in the formation of carbonic acid as per the following reaction.

\[
\text{CO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3 \rightleftharpoons \text{H}^+ + \text{HCO}_3^-
\]

Acid rain or precipitation refers to rain, snow, fog, or gaseous particles that have a pH significantly below 5.6. In general precipitation below 5 can be considered as acidic. Acid rain occurring as rain or snow is referred to as wet deposition whereas dry deposition occurs when gaseous acid particles are directly deposited on the surfaces. Robert Angus Smith a Scottish chemist was identified acid rain and studied it in depth in 1852.

The principal cause of acid rain is the combustion of fossil fuels that produce sulphur and nitrogen emissions and the primary sources are electrical power plants, automobiles and smelters. Power plants, automobiles produce most of the sulphur emissions and nitrogen emissions respectively. The reactions involved in the formation of acid rain are understood from the following reactions.

\[
\text{S}_8 + 8 \text{O}_2 \rightarrow 8 \text{SO}_2
\]
\[
\text{SO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_3
\]
\[
2 \text{H}_2\text{SO}_3 + \text{O}_2 \rightarrow 2\text{H}_2\text{SO}_4
\]

Nitric acid, HNO₃ and nitrous acid HNO₂ form when nitrogen dioxide reacts with water.

\[
\text{NO}_2 + \text{H}_2\text{O} \rightarrow \text{HNO}_3 + \text{HNO}_2
\]

Many equations contribute to the overall formation of acid rain and the reactions often involved a complicated number of steps that depend on the atmospheric conditions. The above reactions shows the formation of sulphuric acid and nitric acid and do not show the numeric reactions that actually occur. Acid rain has number of negative effects on humans, plants, building materials, and entire ecosystem [12].

Hence in order to understand the impact of such kind of rain, the accelerated environmental conditions to the fibre were created through the chemical treatment which contains very minute levels of concentration of H₂SO₄. A clear decrease in the mechanical performance is visualized from the experimental results, which indicates that the fibre was degraded through conditions of exposure viz. in case of individual fibres chemical treatment 1, 2 for OI FV1, 1 for FV2 whereas for oval chain structured fibre 1, 2 for FV1, 1 for FV2.

4. Conclusion and Applications

The present review has given the following impressions. Till today there is a little utilization of the okra fibre and its composites and the literature available is quite small which is evidenced from the list given at the end. Further the OOCSFV1 is a new finding and was identified by the author in 2007 after the fibre was extracted. This kind of fibre with enormous potential properties can be utilised in the preparation of various automobile, structural parts. Acid rain will have a clear affect on degradation of the performance of the composites. So the performance of natural fibres is clearly dependent on the environment where they will grow. Okra FRP composites have shown reasonable insulation ability i.e. dielectric strength.

Acknowledgments

The author firstly thankful to GOD, created diversified natural fibres in a single okra plant. He is further thankful to Dr. Katta Murali Mohan Rao, who has given an encouragement by providing Srikkakulam okra fibre during the intial stage of authors work. The results of the work are explored to the world only with the kind help of the authors’ grandmother Smt. Veeramachineni Jhansi Lakshmi and mother Smt. N. V. L. R. Mani help to manufacture the composites and in all the stages of the research work.
References

[1] Maya John J and Sabu Thomas 2012 *Natural Polymer Volume 1: Composites* (Cambridge: Royal Society of Chemistry)

[2] Sabu Thomas and Laly Pothan A 2009 *Natural Fibre Reinforced Polymer Composites: From Macro to Nanoscale* (USA: Old City Publishing, Inc.)

[3] Srinivasababu N and Sravanthi N 2011 Tensile and dielectric properties characterization of srikakulam abelmoschus esculentus fiber reinforced polymer composites, *National Conference on Processing and Characterization of Materials, NIT Rourkela*, pp. 39.

[4] Shamsul Alam Md, Arifuzzaman Khan G M, 2007 Chemical analysis of okra bast fiber (Abelmoschus esculentus) and its physic-chemical properties *J. Text. Appar. Tech. And Mgt.* Vol. 5, pp. 1-9

[5] Arifuzzaman Khan G M, Saheruzzaman Md, Abdur Razzaque S M, Sakinul Islam Md, and Shamsul Alam Md 2009 Grafting of acrylonitrile monomer onto bleached okra bast fibre and its textile composites *Indian J. Fibre. and Text. Res.* Vol. 34, pp. 321-327

[6] Arifuzzaman Khan G M, Saheruzzaman Md, Rahman M H, Abdur Razzaque S M, Sakinul Islam Md, and Shamsul Alam Md 2009 Grafting of acrylonitrile monomer onto bleached okra bast fibre and its textile composites *Fibers and Polymers* Vol. 10, pp. 65-70

[7] Moniruzzaman Md, Maniruzzaman Mohd, Gafur M A, and Santulli C 2009 Lady’s Finger Fibres for Possible Use as a Reinforcement in Composite Materials *J Biobased Mat. And Bioenergy* Vol. 3, pp. 1-5

[8] Igor Maria De Rosa, Jose Maria Kenny, Debora Puglia, Carlo Santulli, and Fabrizo Sarasini 2010 Morphological, thermal and mechanical characterization of okra (Abelmoschus esculentus) fibres as potential reinforcement in polymer composites *Comp. Sci. and Tech.* Vol. 70, pp. 116-122

[9] Igor Maria De Rosa, Jose Kenny M, Maniruzzaman Mohd, Moniruzzaman Md, Macro Monti, Debora Puglia, Carlo Santulli and Fabrizio Sarasini 2011 Effect of chemical treatments on the mechanical and thermal behaviour of okra (Abelmoschus esculentus) fibres *Comp. Sci. and Tech.* Vol. 71, pp. 246-254

[10] Fortunati E, Puglia D, Monti M, Santulli C, Maniruzzaman M, and Kenny J M 2012 Cellulose nanocrystals extracted from okra fibers in PVA nanocomposites *J App. Polym. Sci.* Vol. 122, pp. 3220-3230

[11] Fortunati E, Puglia D, Monti M, Santulli C, Maniruzzaman M, Foresti M L, Vazquez A, and Kenny J M 2013 Okra (Abelmoschus esculentus) fibre based PLA Composites: mechanical behaviour and biodegradation *J Polym. Environ.* Vol. 21, pp. 726-737

[12] Richard Myers 2003 *The Basics of Chemistry* (Greenwood Publishing Group)

Appendix A.

OIFV–1: Okra Individual Fibre Variety–1
OIFV–1 CT–1: Okra Individual Fibre Variety–1 Chemical treatment–1
OIFV–1 CT–2: Okra Individual Fibre Variety–1 Chemical treatment–2
OIFV–1 CT–3: Okra Individual Fibre Variety–1 Chemical treatment–3
OIFV–2 CT–1: Okra Individual Fibre Variety–2 Chemical treatment–1
OOCSFV–1: Okra Oval Chain Structured Fibre Variety–1
OOCSFV–1 CT–1: Okra Oval Chain Structured Fibre Variety–1 Chemical Treatment–1
OOCSFV–1 CT–2: Okra Oval Chain Structured Fibre Variety–1 Chemical Treatment–2
OOCSFV–1 CT–3: Okra Oval Chain Structured Fibre Variety–1 Chemical Treatment–3
OOCSFV–2 CT–1: Okra Oval Chain Structured Fibre Variety–2 Chemical Treatment–1