

Review

Sustainable Biocomposites: Harnessing the Potential of Waste Seed-Based Fillers in Eco-Friendly Materials

Cristiano Fragassa ^{1,†} , Felipe Vannucchi de Camargo ^{2,†}  and Carlo Santulli ^{3,*,†}

¹ Department of Industrial Engineering, Alma Mater Studiorum University of Bologna, 40133 Bologna, Italy; cristiano.fragassa@unibo.it

² SENAI Institute of Innovation in Polymer Engineering, São Leopoldo-RS 93030-090, Brazil; felipe.camargo@senairs.org.br

³ School of Science and Technology, University of Camerino, 62032 Camerino, Italy

* Correspondence: carlo.santulli@unicam.it

† These authors contributed equally to this work.

Abstract: With the growing concerns over environmental degradation and the increasing demand for sustainable materials, eco-friendly composites have gained considerable attention in recent years. This review paper delves into the promising realm of seed-based fillers, reinforcements and polysaccharidic matrices in the production of biocomposites that are yet focusing on those seeds, which can be considered industrial process waste. Seeds, with their inherent mechanical properties and biodegradability, which are often the waste of production systems, offer a compelling solution to reduce the environmental impact of composite materials. This paper explores the properties of various seeds considered for composite applications and investigates the processing techniques used to incorporate them into composite matrices. Furthermore, it critically analyzes the influence of seed fillers on the mechanical and physical properties of these eco-friendly composites, comparing their performance with traditional counterparts. The environmental benefits, challenges, and limitations associated with seed-based composites from waste seeds are also discussed, as well as their potential applications in diverse industries. Through an assessment of relevant case studies and research findings, this review provides valuable insights into the outlook of seed-based composites as a sustainable alternative in the composite materials landscape, emphasizing their role in promoting a greener and more responsible approach to materials engineering.

Keywords: seed-based composites; waste ligno-cellulosic biomass; seed geometry



Citation: Fragassa, C.; Vannucchi de Camargo, F.; Santulli, C. Sustainable Biocomposites: Harnessing the Potential of Waste Seed-Based Fillers in Eco-Friendly Materials. *Sustainability* **2024**, *16*, 1526. <https://doi.org/10.3390/su16041526>

Academic Editors: Md. Mizanur Rahman and Asif Iqbal

Received: 2 December 2023

Revised: 25 January 2024

Accepted: 8 February 2024

Published: 10 February 2024



Copyright: © 2024 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

In recent years, the urgent need for sustainable and environmentally responsible materials has become increasingly apparent in the face of global ecological challenges. As industries seek alternatives to conventional materials that are often derived from fossil fuels and contribute to pollution and waste, the production of eco-friendly composites containing agricultural waste (or “agrowaste”) has emerged as a suitable strategy [1]. More specifically, this waste, by and large definable as “biomass”, can enter the composites production in form of filler, yet also in form of matrix, in the sense that polysaccharides, such as starch, can be extracted from it. In quite optimistic terms, these materials have been defined as “green composites”; however, the challenges in their fabrication do not appear to be negligible [2]. This type of refuse does take the most different forms, from elongated fibers of various lengths to fillers closer to ellipticity or even sphericity, although often with sharp edges and variable roughness [3]. In general terms, it can be suggested that the use of secondary raw materials leads to a more pronounced irregularity, which has an obvious effect on the final performance of the material, especially in the case of largely industrialized products, such as wood–plastic composites (WPCs) [4].

The value of this approach is that it constitutes a suitable alternative to the disposal of biomass by landfilling, also considering that most of these materials cannot be considered compostable [5]. This occurs especially in case the amount of lignin in the refuse is significant, such that it occurs for many shrubs and trees seeds where the kernel is surrounded by a ligneous coating (acorns are a good example of that), and that are collected from green areas in a generic way [6].

This would move the balance towards incineration or procedures that involve their carbonization, e.g., the production of active carbons from green waste mixed with other systems' refuse, such as end-of-life tires [7] or waste from high added-value productive systems (olive oil) [8]. A more developed option would be obtaining biochar with hierarchical nanostructured surfaces, which can be achieved by carefully tailoring production parameters; this has been obtained with a number of agrowaste types, including shells, such as bael shell (*Aegle marmelos*), or rice husk [9]. These solutions receive further justification for the potential that they have to provide additional environmental bonuses, such as in the case of removal of pollutants, e.g., lead or arsenic in water [10] or dyes [11]. Another possibility in the way of material valorization is offered, for instance, by dye absorption during water treatment; however, this leaves unresolved the seed disposal, such as verified with papaya seeds [12] and jujube (*Ziziphus jujuba*) seeds [13]. Another well-known solution, which is here reported for completeness, is the introduction of seed residue in the biodiesel system, which has been performed in the case of neem oil seed, to serve as sustainable catalyst support [14]. In general, further oil extraction from seeds considered to be non-oily may be performed, such as grape seeds [15]. In any case, the above solutions are likely to increase the carbon footprint and represent a downcycling of the materials.

On the other side and notwithstanding all the above limitations about the performance reliability, which will be discussed further down, the use of biomass-containing composites represents a promising avenue for reducing the environmental impact of various applications. These include, e.g., substitution of carbon-based or even metallic materials for the production of friction-resistant devices [16,17] or brake pads [18,19]; this required also developing wear rate models to better focus on the degradation patterns of agrowaste in this context [20]. To try to summarize the issue, always bearing in mind the biorefinery approach, the use of agrowaste-derived liquids, and essential oils offers natural plasticizers, reactive compatibilizers or active additives; however, when it comes to seed refuse, avoiding incineration is not obvious [21].

The possible economical interest of a secondary application, such as the extraction of bioactive components or oil, as reported above, does not always remove the waste problem and is not practically viable for the majority of vegetable species, where the yield or quality of oil is scarce, which in particular leaves the aspect of seed disposal unresolved. This represents an issue also because the development of materials from crop residues or by-products is increasingly viewed as a method for waste management [22]. However, for smaller seeds, they are often integrated in an undifferentiated biomass (normally defined as "cake", which can nonetheless receive attention also for application in the material field). This is the case also, e.g., for grape seeds [23], whenever they are approached according to a "biorefinery" concept, as described in Figure 1.

Among the plethora of eco-friendly composites, one particular area of interest lies in the incorporation of seed as fillers, hopefully able to work as reinforcements, into composite matrices for the production of compostable (disposable in the organic fraction of waste) materials, therefore with limited amount of ligneous fillers, yet also for obtaining more durable materials with limited water absorption [24].

As a consequence, a more sustainable and added-value step is represented by the exploitation of crop-derived residues, such as seeds, as ligno-cellulosic materials. By harnessing their unique characteristics, researchers and engineers can also develop biocomposites that not only exhibit improved mechanical performance but also possess lower carbon footprints and reduced reliance on non-renewable resources. The first and obvious approach is the use of seed powder, such as in the case of tamarind (TSP), with a relatively

simple matrix for fabrication, typically epoxy, to assess which is the maximum amount of filler that is worth introducing not to hamper the composite properties. In Figure 2, it appears that the tensile and flexural strength, measured according to ASTM D790 [25] and ASTM D638 [26] standards, respectively, degrade for both loading modes when the amount of filler exceeds 40 wt.% [27]. Another study indicated a steady increase in impact strength (measured according to ISO179 standard [28]) for up to 30 wt.% TSP filler content in epoxy, ground to dimensions between 200 and 300 microns, with very limited increase in water absorption, not attaining 2% after 12 days [29].

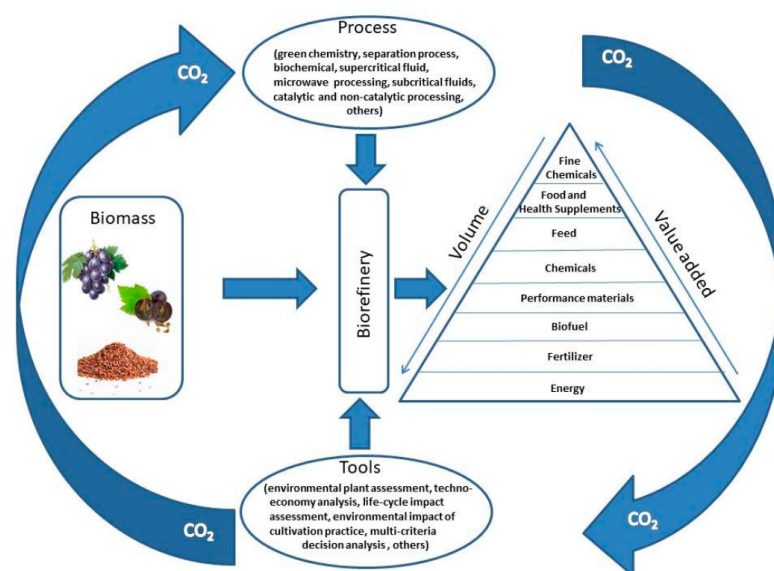


Figure 1. The biorefinery as a concept to realize circular economy [23].

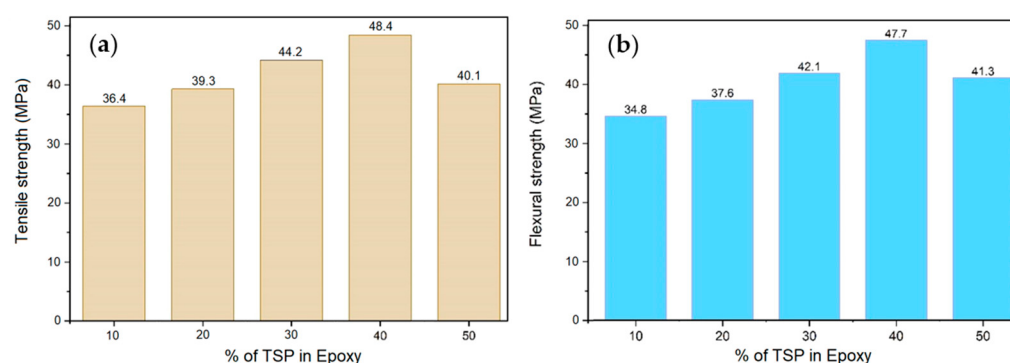


Figure 2. (a) Tensile strength and (b) flexural strength of tamarind seed powder (TSP)/epoxy composites [27].

In other cases, the properties of the whole seed have also been investigated: seeds possess intrinsic mechanical properties under compression, such as for wheat [30], and a significant hardness, though dependent on moisture content and even genotype, such as for pomegranate [31]. For both properties, the non-standard geometry of the seeds requires the development of specific testing methods, which will be further discussed in the following sections.

Moreover, the bio-friendly character of seeds holds the potential to revolutionize the composite materials landscape, as an abundant agrowaste. It is not surprising that studies on the mechanical performance of seeds have been proposed for very large productive systems, such as sunflower [32], rapeseed [33], and castor beans [34]. On the latter, a biaxial compression loading was also performed, as described in Figure 3 [34]. In Ref. [35], indications are offered to the extrusion performance yielded by castor beans, which, after

the load drop due to the episperm breakage comes up to a consistent force in excess of 80 N, due also to the repeatable geometry of the bean (Figure 4).

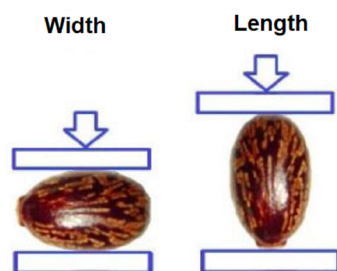


Figure 3. Bi-axial compression loading of castor beans [34].

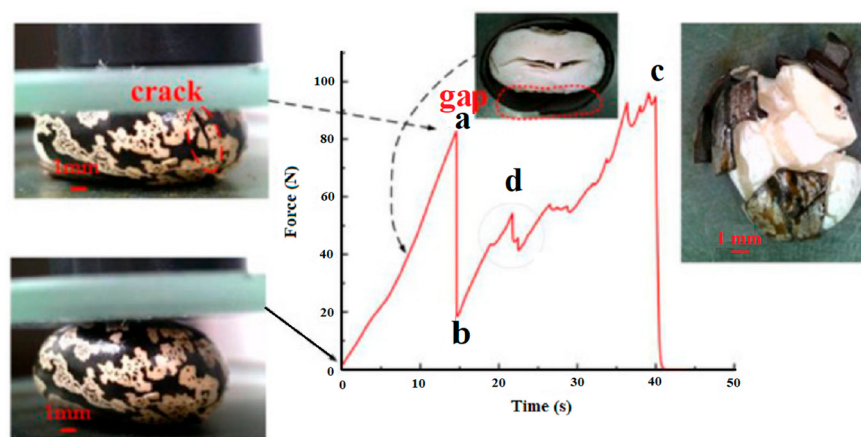


Figure 4. Extrusion loading curve for castor beans [35]. Specific points of the curve: a. First load drop (cracking): top; b. First load drop (cracking): bottom; c. Final collapse; d. Intermediate recovery with load oscillation (yielding).

This interest applies also to very diffuse cultivations, deeply rooted both into wood production and into different food-based products, such as is the case for pine trees [36]. Even for systems, which are diversified, such as is the case for flax, where textiles constitute a large part of the outcome, the insufficient exploitation of seed products may result in growing environmental impact, as indicated by life cycle assessment (LCA) [37] (more details will be given in Section 4.4), which are increasingly integrated into the characterization activity [38].

The assessment of mechanical performance, as declined against moisture content and other environmental parameters, can also be put into relation with the characteristics of the oil obtained. Limited studies do exist in comparing mechanical and physical characteristics of the different parts of the plant; this is, for example, for hulls, kernels, and seeds from *Jatropha Curcas*, which is a source for biofuel, and therefore is likely to produce large amounts of waste from the bulk of the fruit [39]. In this case, the sphericity of fruits, nuts, and kernels was measured, as the ratio between the surface area of a sphere of the same volume of the particle and the surface area of the particle itself, and resulted quite high for all three of them, being equal to 0.95 ± 0.03 , 0.64 ± 0.03 , and 0.68 ± 0.01 , respectively. No specific testing standards were used, yet a deformation velocity of 0.5 mm/s was used, which was demonstrated in testing seeds and kernels to yield a particularly low strength, possibly inducing a reduced toughness of the sample [40]. Despite a geometry not far from sphericity, the compression properties, as observed in walnuts, can vary significantly between the three axes, and, while decreasing with moisture content, would increase with compression speed (three speeds were considered, 0.5, 1, and 1.5 mm/s) [41].

More complex scenarios are also possible in this respect, such as the extraction of cellulose from seed waste; this was carried out, e.g., on mango seeds [42], which appears,

as it will be repeatedly shown in next section, to be among the most used in material production from biomass. In similar cases, lignin and hemicellulose have been removed by alkaline treatment, e.g., on mango seed pods, to obtain cellulosic short fibers [43]. This appears to be a limiting factor though to consider seeds as just another source of cellulose and it leads to an increased amount of waste and chemical use.

This review paper delves into the realm of seed-based composites and their connection with further applications of seeds, exploring the diverse range of seeds that have been investigated for their significance when employed as fillers or reinforcements in composite materials. Botanical names of the cultivation from which the biomass is obtained are also often indicated, along with the common names, according to the use that is conducted in the literature, where often either of these are used. Of course, in terms of the production system, especially related to food, this has an environmental sense whenever the seeds are either produced in excess or they represent in themselves a waste, not being adapted to use. This is the case for non-edible seed cakes, such as those from neem seed protein [43] and *Pongamia pinnata* seeds [44], from which the development of a “green” resin has been proposed, and the previously mentioned jatropha seed cake, which served as the reinforcement for epoxy resin [45]. There are more substantial cases in which the extraction of starch from seed waste has also been proposed to serve for the production of bio-based resin. This was suggested for non-edible avocado seeds, whose starch has been blended with cellulose at different scales and cross-linked to reduce water absorption and propose a “green” resin [46]. Some literature did also consider seed hull waste: its principal application still involves their role as the precursors for the fabrication of active carbons (e.g., *Brachystegia euricoma* [47], *Prosopis Africana* [48], or castor beans [49]): however, other destinations were also possible. For example, sunflower seed hulls for pectin composites [50], or pumpkin seed hulls for dye removal from water solutions [51]. For larger seeds, such as mango, even the separation of the different parts was necessarily performed before grinding and introducing in the composite formed with a polylactic acid (PLA) matrix [52]. In particular, kernel and integument offered distinct properties when examined under X-ray diffraction (XRD) for crystallinity measurements, as reported in Figure 5. A similar study on mango seed powder/PLA composites reported that the use of plasticizers, such as tributyrin and triacetin, did improve fiber/matrix compatibility, while on the other hand, it did not affect compostability properties after 12 weeks [53].

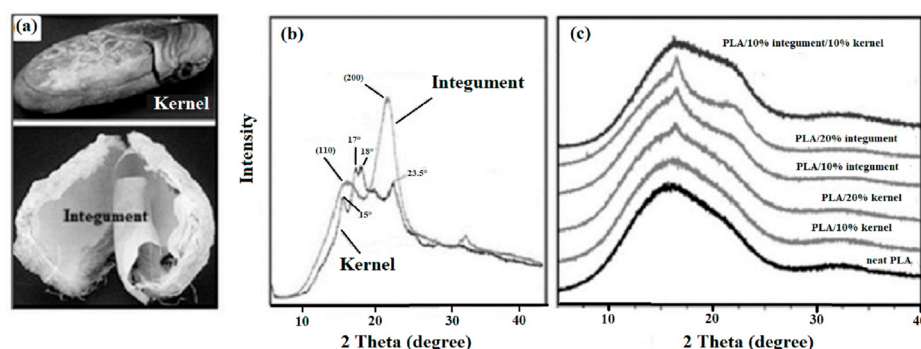


Figure 5. Properties of the mango seed composite. (a) Mango seed parts (kernel and integument) considered. (b) Crystallinity measurements of the two different parts. (c) Crystallinity measurements of different composites with PLA and including the two different seed parts [52].

In other cases, the seeds are not powdered, yet fragmented, in which case the edge geometry of the pieces obtained also has an importance on the performance. In Ref. [54], unsaturated polyester resin is added with date palm seed particles with 0.5, 2-, and 2.8-mm size with loadings up to 25 wt.%. The hardness grows with higher particle dimensions, whereas the tensile performance does suggest limiting to the lowest one. This means the filler dimensions can be tailored, at least to a point, to suit the needs of the prospected application. It needs to be clarified of course that the seeds are supposed to be of limited

dimensions and with simple structure to fit the purpose, otherwise they need to be used in form of powder then sieved so to use only particles of dimensions compatible with the composite fabrication. To give an example, in Ref. [55], where palm date seed powder has been used as filler in glass/epoxy composites, the average granulometry was approximately 75 microns. In some cases, seed-derived material can offer a multifold action, involving not only mechanical potential, strictly linked to filler morphology, but also intervening on polymer processing, hence modifying its rheology. This has been experimented, e.g., with the addition of sunflower seed husk flour in an acrylonitrile-butadiene-styrene (ABS) matrix [56].

The focus of the review is generally to provide an in-depth analysis of the influence of seed fillers on the mechanical and physical properties of eco-friendly composites. By understanding the structural effects of seed incorporation, researchers can better design composites tailored for specific applications, while adhering to sustainable practices.

Furthermore, the challenges and opportunities associated with the processing techniques used for integrating seeds into composite matrices are also discussed. The scalability and viability of seed-based composites in industrial settings are also explored, shedding light on the practicality of these materials for real-world applications.

Overall, this work aims to present a comprehensive assessment of the state-of-the-art in seed-based composites, highlighting their potential as a game-changing solution in the pursuit of eco-friendly materials. Through an evaluation of key case studies and research findings, we hope to inspire further advancements in this field, contributing to a greener and more sustainable future for material engineering.

2. Overview

This present review has the following structure:

- Seed-based fillers/reinforcements: providing an overview of various seeds that have been studied for their potential as fillers or reinforcements and discussing the unique properties of seeds that make them suitable for composite materials (Section 3.1).
- Processing techniques: exploring the different methods used to incorporate seeds into composite matrices and discussing the challenges and opportunities related to processing seed-based composites (Section 3.2).
- Mechanical and physical properties as fillers: analyzing the effect of seed fillers on the mechanical and physical properties of the composite materials and comparing the performance of seed-based composites with traditional composites (Section 4.1).
- Use of seed products as composite matrices: The application as filler in bio-composites is not the only one suitable for seeds use. It is also possible to use polysaccharide seeds for the production of starches to serve as matrices (Section 4.2).
- Characterization for the construction industry: Other sectors, which are actively searching for sustainable fillers, able to avoid or reduce resource depletion, are also of interest for seed-derived materials. This is the case for construction industry, where, the majority of works on seeds in materials can be found (Section 4.3).
- Environmental impact: assessing the environmental benefits of using seed-based fillers compared to conventional fillers (e.g., glass fibers), and discuss the biodegradability and end-of-life considerations of seed-based composites (Section 4.4).
- Comparative analysis: comparing seed-based composites with other types of eco-friendly composites (e.g., natural fibers, recycled materials) in terms of performance, cost, and environmental impact (Section 4.5).
- Applications and industries: identifying potential applications and industries where seed-based composites can be used effectively and discussing any commercial or industrial implementations of seed-based composites (Section 5).
- Conclusion: recapitulating the main findings and arguments discussed and highlighting the potential of seed-based composites as a sustainable alternative in the composite materials industry (Section 6).

3. Materials and Processes

The question of hardening and strengthening composites using biological materials or agrowaste has a significant impact, which is not strictly limited to the use of bio-based matrices, though it can also have some significance in the case of conventional; hence, oil-based ones. This is in the case of polymer composites. On the other hand, it can also be relevant as regards ceramic-based composites, which are typically used in the construction industry. In both cases, the geometry of whole seeds, or seed-derived filler, does represent one of the principal caveats for successful use of them.

3.1. Seed-Based Fillers/Reinforcements

Hereinafter, an overview is provided of various seeds that have been studied for their potential as fillers or reinforcements, discussing the unique properties of seeds that make them suitable for composite materials. When the use is occasional and more interesting for the techniques used in materials development than for the characteristics of the seed, the relevant studies will be reported in the respective sections.

There is a wide number of studies on the use of powdered seeds of small dimensions in composites; here, an attempt is done to introduce those seeds that are the most largely used in composites and their relevant production systems. This would also expose the potential applications, excluding those connected with carbonization, gasification, and generally recovery, which compete with the use of seeds in composites.

It is noteworthy that most seeds that have found an application into composites do belong to a productive system directly correlated with food, normally for edible oil extraction. For completeness' sake, it is noteworthy evidencing that seeds proved sufficiently adherent also to a matrix constituted by tannery shavings (leather waste) [57], which on the other hand have been also proposed, in a chromium-free version, as the reinforcement for self-produced thermoplastic starches (TPS) [58]. However, the largest part of ideas/proposals for seed introduction in materials do directly concern food waste.

In particular, the direct production of biodegradable composites by the extrusion of a mix between two food wastes, namely rapeseed cake and brewer's threshing (barley husk) in different proportions (30:70, 50:50, 70:30) has also been anticipated, the advantage being that the material did not require any additional processing [59]. The question in this regard is the density of agglomerates, which is seen as increasing with rapeseed content.

This is again the case for some cultivations that pertain to large productive systems. Examples can be date seeds, which, apart from nutritional significance, are also used in oil extraction [60], brewing [61], and even as a substitute for coffee powder [62]. Date seeds have a characteristic that is definitely of interest for introduction in composites: though being generically elliptical, their geometry is very limitedly affected by the environmental conditions, in terms of distance between the centroids [63]. This suggests that the variability between species in terms of mechanical performance is minimal.

A substantial number of works on composites are also available involving the use of olive pits powder, for which other uses have been proposed, such as in capacitors with high energy and power density [64], or in the exploitation of their antimicrobial and antiradical properties [65]. Interest has also been raised recently with peach seeds, which, as is the case with kernels, are well known for the extraction of bioactive compounds [66]. Some other fruit seeds, such as cherry pits, for their geometry particularly close to sphericity, have also been proposed for use as aggregates in cement [67], while their controlled porosity raised attention for application in lithium–sulfur batteries [68]. In other cases, where the complexity of the structure of fruit seeds is considerably higher, and powdering does not appear to be a facile option such as, e.g., for cactus fruit seeds, the direct extraction of polysaccharides proves to be a more viable route for their exploitation [69]. Whenever the dimension of the seeds is very small, such as in the case of tomatoes, the approach does better concern a general use of tomato waste including, e.g., seeds and peels, which have been studied over decades, yet which prevalently contain polysaccharides and proteins [70]. This allowed for, e.g., performing the production of biodegradable pots, in combination

with hemp fibers [71], while recently, a more comprehensive review on the use of tomato waste in view of bio-based materials is delivered in Ref. [72].

It is also worth mentioning that also in the case of prickly pears, probably in contrast with first evidence, most uses are here again connected with the food sector [73]. As far as their seeds are concerned, oil was often analyzed and characterized, as a food supplement and for its content of fatty acids [74], and in other cases connected with the production of biofuel [75,76]. Other uses of prickly pear products are related to materials, e.g., for the development of lightweight concrete [77], to the synthesis of bacterial cellulose [78], and to the extensive use of mucilage for film production [79]. Among the larger fruit production systems, however, other kinds of niche products pertaining to the food system and supplying versatile seeds, have been proposed. This is the case, as exposed also in the introduction, for tamarind seeds: here, the high content in polysaccharides (50–57% in the whole seed, and 67–72% in the kernel) [80] allows applications for film production. This occurs in blends in other typical polysaccharides, such as alginate, where a combined film with tamarind seed was also proposed as a drug delivery system, experimenting with diclofenac [81]. Another seed, which has a niche market in the food sector, is pistachio, which, also due to its relevant porosity that enables resin penetration [82], equally has been used in composite fabrication with a large number of matrices, both thermoplastic and thermosetting [83].

A great deal of attention has also been elicited in the case of sunflower seed cake, which is perceived as a natural composite for its presence of around 40% of lignocellulosic fibers from the husks of sunflower seed, possibly to be linked with intrinsic biopolymers, such as globulins, which specifically show a thermoplastic behavior. This hypothesis, though raised in Ref. [84] (Figure 6), did find limited practical application so far, yet it appears to be a very sustainable solution for the absence of the requirement to use a further polymer matrix, extraneous to the original one. A recent application indicated that globulins could serve as the matrix for sage seed hydrocolloid with a potential use as hydrogel for the food and pharmaceutical sector [85]. More traditionally, yet possibly with easier feasibility, the use of sunflower seed cake as the filler in thermoplastic composites was also proposed [86].

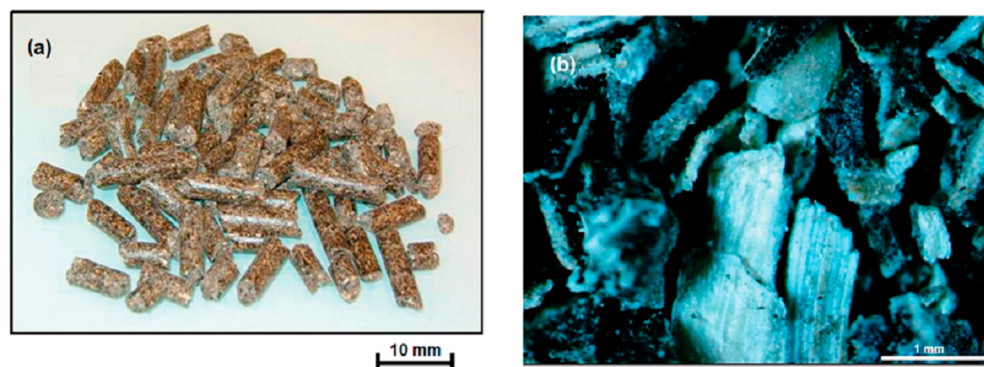


Figure 6. Sunflower seed cake (SFC) pictures: (a) SFC pellets and (b) crude ground SFC (optical microscopy 30×) [83].

3.2. Processing Techniques and Composites Fabrication

For the seeds to be used as fillers in composites, the process normally involves the crushing of the seed into powder, or the use of the seed in a mix or agglomerate with other matter obtained from production, to be defined as “cake”. The use of the whole seed does not appear to be a very likely occurrence for the geometrical limitations in the composite fabrication, even with small seeds. However, a number of studies exist, which report data over compression performance of whole seeds (or nuts, including seeds, such as is the case for acorns). Some relevant data are reported in Table 1, which show a very large range of values, which is further influenced by moisture and geometrical factors, such as sphericity and roundness, i.e., the more or less pronounced smoothness of edges.

These values though preserve their significance as an indication of the maximum strength obtainable from the filler.

Table 1. Compression data on whole seeds.

Plant	Sphericity	Max. Compression Load (N)	Corresponding Moisture Content (%)	Ref.
Corn	0.6–0.75	480	25	[87]
Safflower	0.58–0.63	33	6.5	[88]
Cumin	0.53	50	7	[89]
<i>Dioclea reflexa</i>	0.84	1500	12	[90]
<i>Shorea robusta</i>	0.71	247	10.5	[91]
Black pepper	0.94	75	9	[92]

A typical compression curve is reported in Figure 7 [90], together with the different dimensions of the seed, which shows a particularly high sphericity, under compression.

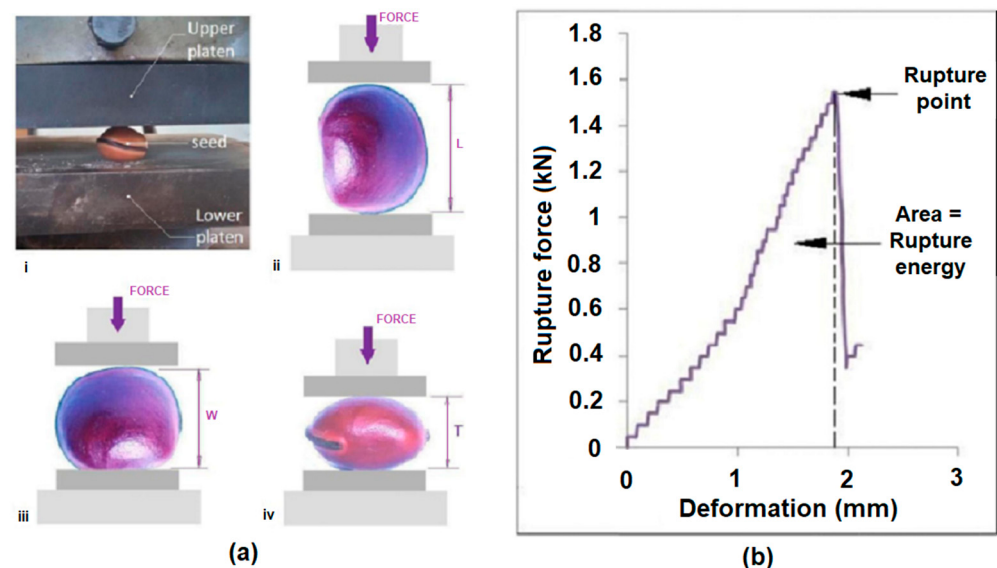


Figure 7. Compression tests on *Dioclea reflexa*: (a) i Compression tests; ii, iii, and iv. Different axes; (b) compression curve along the longer axis [90].

In the case that the bare seed is used, some parts might be particularly valuable and practically used. This occurs for the extraction by mechanical stripping of the fibrous component of the seed that has sometimes been carried out, such as with poplar seeds [93]. Even in an important sector, such as cotton production, waste from seed opening for fiber extraction might not be devoid from fibers itself [94,95]. The awareness of this situation was brought to the proposal for a biorefinery approach, also in the case of the second major seed-extracted fiber after cotton, kapok (*Ceiba pentandra*) [96]. Of course, the length of fibers obtainable from waste products is much shorter and not of interest for textile production, not normally exceeding a few millimeters or, at best, centimeters.

Grinding into fragments or powder is carried out mechanically and a factor that has obviously a significant importance of obtaining a sufficiently strong filler–matrix interface in the composite is the granulometry distribution. The simplest way to introduce the fillers in composite is a manual procedure with agitation (stir casting) with thermosetting matrices, such as epoxy. This is due to its simplicity and relative effectiveness.

Examples of the previous procedure are reported below, such as is the case for mango seed composites [97]. Mango seed is a single embryo (approximately 40–70 mm long, 30–40 mm wide, and 10 mm thick), housed in the seed coat, around 1–2 mm thick, which was extracted by boiling the seeds, separating it manually and grinding to a fibrous and

flaky small size of 12–25 microns. Olive seeds also represent a classical filler, which was attempted, e.g., in Ref. [98], in formats like 300, 450, and 600 microns and in amounts of up to 18 wt.%, again in epoxy. Date palm seeds have been added to form a hybrid composite to glass/epoxy laminate in an amount of 10 wt.% with a mean size of the particles being equal to 75 microns [99]. This resulted in a reduction of wear loss and in improved toughness, though the application of the filler did require a pre-treatment using sulfuric acid and then a thermal processing up to 80 °C. Always with date palm seeds and using a thermosetting matrix, yet a vinyl ester one, the introduction of up to 50 wt.% of date palm seed powder was possible: this was also due to the more refined grinding to a dimension spanning between 30 and 60 microns [100].

The use of seed fillers with thermoplastic matrices does appear less diffuse for obvious difficulties linked to temperature processing and rheological behavior of the mixture. Dealing with thermoplastics, the perspective may change, in the sense that the biodegradable character of biomass fillers can be exploited by coupling it with a bio-based matrix: in sectors, such as biomedical materials, the presence of poly (lactic acid) (PLA) as a matrix is predominant [101]. However, since starch might also be extracted as a bio-waste, it does not come as a surprise that examples are reported as concerns the filling of thermoplastic starch (TPS) particles cast with two different types of seed hairs from trees, namely milkweed (*Asclepias syriaca*) and silver poplar (*Populus alba*) [102]. The effect of this modification was particularly detrimental over the elongation of TPS, nonetheless. Another example was obtained with date pits that were introduced in an amount of up to 50% in polystyrene and then heat pressed to produce the final composites with the idea to promote their possible use as thermal insulators [103]. Using date seeds and biopolyesters, namely poly(buthyleneadipate-co-terephthalate) (PBAT) and poly(lactic acid) (PLA), a composite was also produced by melt mixing at a temperature of 145 °C with PBAT and of 170 °C with PLA up to a filler content of 40 wt.% [104]. Melt mixing with seed powder, namely of *Mimulus elengi* shell, was also applied with polypropylene and different amount of powder, at a temperature of 180 °C and in different amounts, though very limited (not exceeding 10 wt.%), to be proposed for the application in automotive dashboards, or other furniture panels [105]. Date palm seeds powder has also been introduced in recycled linear low-density poly(ethylene) in amounts up to 30 wt.% and processed by twin screw extruder followed by compression molding; however, the crystallinity was reduced by the effect of the filler from 49 to 29% [106].

Another possible use is pertinent to an increasingly developing sector, namely the introduction of biomass powders as component for fillers to be employed in 3D printing filaments, especially realized using PLA; specific reviews exist in this regard, e.g., Ref. [107]. A recent study did involve the use for this purpose of tamarind seed kernel powder, which had some role in the production of composites [108]. In this specific case, the powder was sieved to obtain a granulometry range, between 50 and 100 µm, adapted for introduction in the filament, though not possibly exceeding a concentration of 2% to offer tensile properties enhancement and effective melt flow due to the difficult control of porosities [109]. In other cases, the presence of seed waste is concealed into a composite waste biomass, including peels and other mainly cellulosic material, rather fibrous such as it is the case for tomato (*Solanum lycopersicum*) [110]. A scanning electron microscopy (SEM) image of the above is represented in Figure 8, where the non-uniformity is appreciable. Notwithstanding this limitation, a 10 wt.% filler was possibly introduced in the filament, with some improvement of the tensile strength (from 27 to 30 MPa) at the expense of deformation (from 58% to 36%) at 0° raster angle (tool path vs. building table). Some influence of the latter was also revealed, with 0° preferable to ±45°.

The potential of 3D processes when introducing seed powder appears still to be elucidated. An attempt has also been carried out as for 3D bioprinting of medical scaffolds, showing some potential of cartilage repair, though using a complex mixture of alginate/halloysite nanotubes/methylcellulose/Russian olive (*Elaeagnus angustifolia*) seed powder, the latter having some tradition for wound healing in traditional medicine [111].

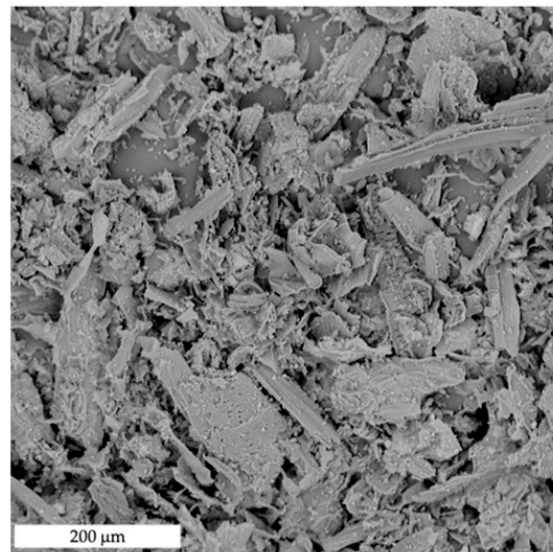


Figure 8. Tomato waste biomass including seed, peels, fibers [110].

4. Properties and Sustainability

Achieving a real sustainability for the application of seeds and related powders into composites would mean attaining a number of objectives, which can be clarified further in this section:

1. Obtaining sufficient properties that would improve the wearing out pattern of the composite and allow it to be used for applications involving some duration of use (i.e., not being limited to single use) [112]. This will have to happen also for used for which wear is expected and is important it to be predictable, i.e., in the tribological field [113].
2. Be ready for introduction in composites with limited, if any, chemical/thermal/physical treatment, providing an adequate interfacial strength and quasi-uniform adhesion with the matrix, nonetheless. A wealth of possible methods does exist, though many may be aggressive and result in further chemicals' discharge [114]. Represent a believable alternative, able to be successfully proposed and applied, to the incineration of the biomass involved, in view of its perceived and demonstrated structural and functional quality in the developed composite [115]. In Figure 9, some indications are provided, which particularly suggest the position of materials from agrowaste, among which are seed-based ones as a source for the development of new bio-materials (although the term is controversial, being also dedicated to those designed for interaction with human body; hence, biocompatible) [116]. This would suggest, for example, in our specific case the application, e.g., of seed derivatives in low-value items, such as asphalt modifier, normally in the form of biochar [117]. This was applied in the case of *Mesua ferrea* particles in excess of 150 microns [118], although in other cases, such as for apricot seed shells, the modification was carried out at more manageable temperatures, i.e., 180 °C [119]. This is obviously a better solution than waste production, and does not pertain to a real circular economy concept. As a result, further considerations on the construction industry use of seed-derived materials, as exposed in Section 4.2, will offer more exposure to studies that involve limited treatment of waste for its introduction.

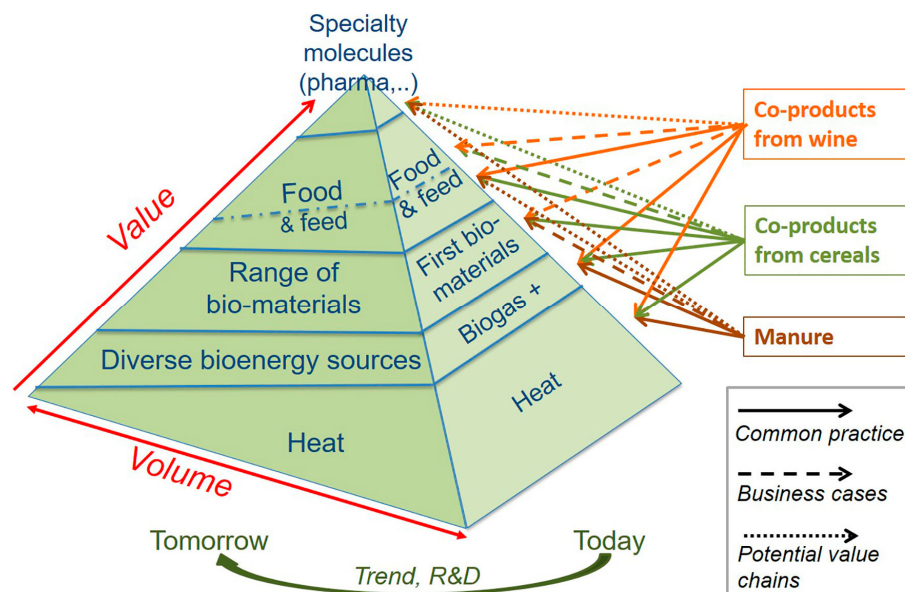


Figure 9. The position of bio-(based) materials from agrowaste in a circular economy concept [116].

4.1. Mechanical and Physical Properties as Fillers

The study of mechanical and physical properties of seeds for their use into materials and more specifically for their development in biocomposites has involved a large number of factors, which are briefly summarized in Figure 10.

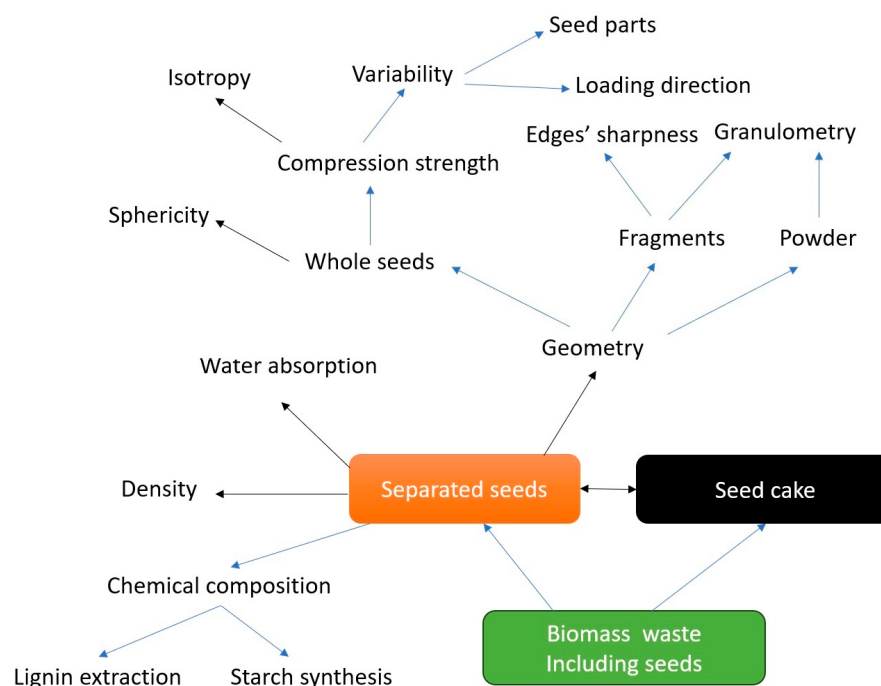


Figure 10. Factors involved in the use of suitable seeds into materials.

The study of the mechanical performance of seed-based composites is in some cases restricted by the fact that a limited tenor of filler is introduced, which, if too small, can raise some concern over a possible greenwashing approach and a limited usefulness of the process in terms of the process. There is an obvious relation between the amount of filler and its granulometry, in particular in the case of the production of composites with considerable thickness (over a few mm) to be used as particleboards. In particular, the

comparison between a number of studies where granulometry is overtly reported is offered in Table 2.

Table 2. Examples of bio-composites with powdered seeds.

Powder Source	Resin	Diameter (μm)	Max. Amount (wt.%)	Ref.
<i>Euterpe oleracea</i>	Castor oil PU	Less than 70	12.5	[120]
<i>Moringa oleifera</i>	PBAT	41 ± 10	10	[121]
<i>Phoenix dactylifera</i>	Epoxy	Up to 200	10	[122]
Pistachio	PMMA	Up to 212	12	[123]
Almond shell	PBS	150 (average)	30	[124]

PU = Polyurethane; PBAT = Poly (butyrate adipate terephthalate); PMMA = Poly (methylmetacrylate); PBS = Polybutylsuccinate.

However, in itself, a large amount of filler might not be always necessary; in Ref. [125], using *Delonix regia* (Dr) seed filler in a recycled low-density polyethylene (RLDPE), a fourfold increase of tensile strength is observed just by 4 wt.% addition of it, also with statistical repeatability. This can be explained, given the quite high granulometry of the particles (over 105 μm), by their capability to hinder fracture, which is lost by the excessive packing obtained at higher particle contents. As a whole, the particle size has an influence on the tensile strength, which implies that over some dimension of the filler, a decrease of performance is revealed, worsening the higher the amount of particles introduced. This is observed in Ref. [54] with date palm seeds ranging from 0.5 to 2.8 mm, and optimized in this sense in Ref. [99], where wear loss was demonstrated to be largely dependent on abrasive paper grit size, therefore suggesting a typical behavior for friction-resistant materials. Palm date seed (PDS) fillers are, however, among the most promising in mechanical terms and have, in fact, been attempted also in hybrids with glass/epoxy composites, in amounts up to 50 wt.%, obtaining a tensile and flexural strength of 271 MPa and 241 MPa, respectively [126]. PDS was also proposed in combination with other filler, namely alpaca wool in a polypropylene matrix, both in the maximum size of 100 microns [127]. The optimal content for tensile, flexural (according to Ref. [27] and Charpy impact strength (according to [29]) was achieved for a respective content of 15 wt.% palm seed and 20 wt.% alpaca wool powder.

In principle, biodegradable matrices should be used with biomass fillers: the most popular and widely used being poly (lactic acid) (PLA) [128]. In the case of PLA/olive pits composite, two different grinding methods (A, planetary ball mill, and B, centrifugal rotor mill), which led to different particle size and a different granulometry (rounder for A, flakier for B), as shown in Figure 11, were proven to affect, very limitedly, the thermal properties of the filler. On the other side, the tensile modulus of PLA composites with olive pits powdered according to the B-method was higher by 18% with respect to A-method, keeping constant a 20 wt.% filler content [129]. Another natural resin whose use has been proposed with seed-derived materials is Dammar resin, which is obtained from trees of the Dipterocarpaceae family [130], and more recently used, to compensate for its properties, also in blends with other synthetic resins, such as epoxy [131]. However, the use with pure Dammar resin together with 40 wt.% crushed sunflower seeds was attempted, and it was suggested that, given their limited tensile strength (in the order of 10 MPa) their use would be more of interest in terms of core for sandwich structures, therefore acting more naturally in compression [132].

Another biodegradable, yet not bio-based, matrix that has found some interest in being filled with seed waste products is polycaprolactone (PCL), whose principal limitation lies in its low softening temperature of approximately 60 °C, yet has found some application in biocomposites, also from agrowaste, whenever their use is restricted to ambient temperature or around it [133]. As a matter of fact, the use of PCL with seeds has been prevalently limited to parts of these. This has been the case for cocoa bean shells (CBS), where the introduction of 30% CBS led to an increase of the Young's modulus for PCL from 439 to 740 MPa, though at the expense of some tensile strength [134]. In another case, the fibers from borlotti and

green beans were extracted to be used as a reinforcement for PCL, and their introduction in the amount of 40 wt.% led to a Young's modulus in the excess of 1200 MPa, again with a substantial decrease of tensile strength [135].

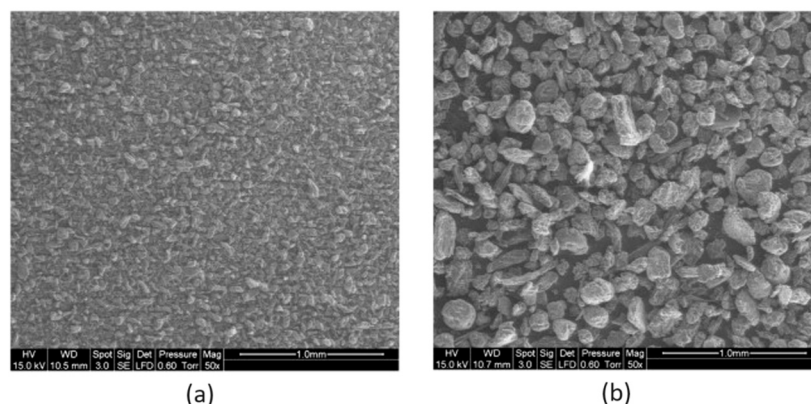


Figure 11. Olive pits ground according to different methods: (a) planetary ball mill; (b) rotor centrifugal speed) [129].

A particularly comprehensive analysis about mechanical, thermal, and water absorption properties of seed-based composites has been carried out dealing with *Polyalthia longifolia* (mast tree)/vinyl ester matrix composites, which were introduced in amounts from 5 to 50 wt.% in the polymer matrix, though the properties declined above 25 wt.% filler. Data indicated a large variability, namely a tensile strength of 9–32.5 MPa, a flexural strength of 44–125 MPa, an impact strength of 10–31.1 kJ/m², and a Barcol hardness of 23–36.5 [136]. The difficulty in increasing the amount of filler over a certain amount and obtain an advantage in terms of mechanical properties was also encountered in the case of pinecone residues, where the introduction of 30 wt.% filler did result an increase of 11% of both tensile strength and hardness, whereas tensile elongation decreased by 48% and impact strength by 30% [137].

A further possibility is the introduction of powders to a different dimensional level, typically nano- vs. micro-, for the improvement of the properties of other composites that may be of limited interest as such. This has been the case when employing tamarind seed nanopowder as an additional filler for *Luffa cylindrica* composite in an epoxy composite [138]. *Luffa*, which is a natural sponge, has had some limited applications in materials, in particular trying to tailor the chemical treatment required for composite fabrication, and is in continuous search for optimization as for the number of layers and stiffness, due to its cellular structure [139]. In Ref. [140], a 60:40 epoxy *luffa* composite has been filled with tamarind nanopowder (TNP) with 7.5% TNP resulting in the most promising results, with, more specifically, a 18% improvement of impact strength and a 16% improvement of both tensile strength and flexural strength, while compression strength only grew by 7.5%.

4.2. Use of Seed Products as Composite Matrices

Despite the fact that, as reported above, biocomposites have been produced using seeds and relevant powders as fillers, a large number of materials obtained from the seed system have been reported, which can be in search of relocation for use in this field. In principle, other than the extraction of oil, also the synthesis of starch from seeds containing sufficient amounts of polysaccharides, as in avocados, has been proposed [141]. The process of starch synthesis from seed waste includes the application of a limited tenor of chemicals and water for the purpose. In particular, after grinding and soaking in sodium sulphate solution, the obtained mixture was homogenized, filtered, and washed with deionized water, before settling. The crude starch extract was then separated from discarded supernatant and was dried at 50 °C for one day after washing.

The advantages of the extraction of starch from seeds does provide an important link between food-based waste and its possible application in other sectors. This is especially in view of the multifaceted characteristics of the starch products, which does not hinder use of seeds also for other objectives, depending on the very chemical characteristics of the single seeds, therefore, by some preliminary screening of these [142] (Figure 12). In the specific case of avocado seed, given their non-negligible dimensions, exceeding a few centimeters, hence with significant strength and stiffness, this would even extend to wood replacement products [143].



Figure 12. The economic system of starch products, which is parallel and complementary to the possible use of seeds and relevant waste [142].

However, research was needed gradually to concentrate on the starch-rich seeds discarded from food production to evaluate whether they may serve as composite. An example of these fruits is litchi (53% starch), which nonetheless contains a limited amount of the structural polysaccharide, amylose (7.6% against 29.2% of a typical starch for bioplastics production, corn), though there is more limited variability of granule size and extractable through both alkali and acidic routes [144].

Another possibility of exploitation of seed-based waste is in the introduction of starch–mucilage blends, where the mucilage of two main seeds has been exploited, namely from *Plantago psyllium* and chia [145]. In the former’s case, film with potato starch were formed with thicknesses between 120 and 200 microns for edible packaging purposes [146], while in the latter, mucilage acted as the matrix with starch nanocrystals [147].

Starch extraction did also elicit some other characteristics, such as the possibility of controlled drug delivery, as is in the case of jackfruit (*Artocarpus heterophyllus*) seeds [148]. With cress seed (*Lepidium sativum*) gum, able to offer a hydrocolloid, the application of matrix blend, formed by alginate and soy protein, was effectively tested for the delivery of curcumin [149]. Another possibility to obtain starch-based composites reinforced with cellulosic husk from the same origin was also carried out using pehuen obtained materials [150]. The development of active packaging with antibacterial properties against food typical pathogen agents was also proposed by the addition of grapefruit seed extract to carrageenan films [151].

4.3. Characterization of Seed Products for the Construction Industry

Some potential has also been elicited in terms of application of seed-derived materials in the construction field, where, due to resource depletion, the use of secondary raw materials is increasingly growing [152]. In particular, one of the principal issues in the construction industry is the envisaged substitution of aggregates for concrete extracted from quarries (natural aggregates) (NA) with recycled aggregates (RA). The latter have been lately also obtained from generic biomass, such as wood bark, where the presence of cellular structure did allow yielding a foamy aspect to concrete [153]. As is the case also for composites, it can be noticed that some of the applications proposed the carbonization of the biomass to allow for its use as a filler. This occurred, e.g., for bottom ashes from biomass incineration [154] or olive waste ashes; in this case, in addition to recycled aggregates [155].

This was in passing to as-received materials, not involving an incineration stage, in the case of palm date seeds, as, e.g., the filler for bricks, therefore in combination with traditional construction materials, such as clay and straw, where it overcame the performance of olive husk [156]. Potential was also shown by coconut shells in the construction industry, often in the form of use of ashes in concrete [157], yet also in the ligneous form for the production of aggregates [158] or fiberboards [159]; however, coconut shells do border into the field of natural fibers, whose use has widely been widely recognized in the literature [160]. The use of coconut shell aggregates demonstrated to be adapted for replacement of naturally extracted aggregates concrete (NAC), offering in a Class III concrete a compression strength at 3 and 28 days equal to 93% and 88% NAC, which was therefore considered acceptable for use [161].

This allowed for extending the field of application to avoid combustion of other very abundant fillers, such as date seeds. Another proposal concerned their use in the amount of in unsaturated polyester matrix for thermal insulation boards, in a granulometry of up to 2 mm and a quantity reaching even 70 vol.%, though this ultimately resulted in a water retention in the order of 15%. This suggested limiting the amount of date seeds to 50 vol.%, which allowed for keeping thermal diffusivity at $0.096 \text{ mm}^2/\text{s}$ and water retention not exceeding 3.44% [162]. Other application of date seeds (DS) in thermal insulation boards involved application of bio-polyesters, such as poly(lactic acid) (PLA), with an amount of DS of up to 40 wt.%, which yielded thermal diffusivity of $0.0342 \text{ mm}^2/\text{s}$, and water retention of 5.6% over 24 h [163]. It is possible also to observe the difference between various modes of introduction for date palm fillers. In particular, a study on the replacement of gravel with palm kernel shells (12 mm max. dimension), crushed palm kernel (1.18 mm max.), or date seeds ash in concrete reported that for a 10% replacement the decrease in compression and flexural strength was limited and did not match the amount of recycled aggregate introduced [164].

However, an evaluation of the introduction of up to 20% of crushed rubber seed shells into cement did indicate a reduction of both slump and compressive strength due to the difficulty of cement to effectively coat the irregular particles of biomass [165]. Further studies carried out by improving mixing and descending to an adequate fineness of the biomass aggregate did lead to some improvements up to 4 vol.% of rubber seed powder aggregate [166]. In the case of sunflower seed waste, their introduction as aggregates in cement was also attempted, up to 30 wt.%, which despite a large reduction of mechanical performance, greatly improved water absorption at 7 and 28 days. This would suggest the need for a retuning of water/cement ratio in production, which might eventually result in some cost reduction [167].

4.4. Comparative Analysis with Conventional Composites

A few comparative studies exist that do emphasize the possibility to replace wood-based composite fillers with seed-based ones. This is also perceived as significant in terms of compression strength, where epoxy composites including rubber seed shells and walnut shells up to an amount of 20 wt.% overperformed Sundari wood (*Heritiera littoralis*) by 792% and 722%, respectively [168].

In Ref. [169], for example, alternatives to polypropylene boards filled with radiata pine wood are proposed, namely macadamia shells, pinecones, and eucalyptus capsules. Other than the obvious cost reduction achieved with some decrease in terms of tensile, flexural, and impact strength, suggestive evidence points out to the fact that the introduction of seeds allows for reducing the anisotropy of the composite. This outcome has been exploited in other cases by the introduction of a powder-like material of ligno-cellulosic origin in combination with a fibrous one in the same composite, such as for kapok seed powder in kenaf fiber composites, also with an environmental impact reduction by not requiring the application of fiber treatment [170]. The fine-tuning of the fibrous-seed powder combination would offer the highest performance is by no means obvious and does require a comparative assessment of some different configurations. This was found out, for example, in the case of Indian almond fibers against neem seed powder [171]. Another interesting factor does concern the fact that the experience accumulated over ligno-cellulosic fillers is substantial and extends over seed-based composites. For example, the application of the maleinization process to increase the compatibility of polyolefin matrices, such as polypropylene, and their blends with natural materials [172], proved also to be suitable for the introduction of date palm seeds in composites [173].

4.5. Environmental Impact: LCA Studies on Seed-Based Materials and Related Systems

A further aspect to be considered, to try to evaluate the sense of the operation when it comes to producing seed waste-based materials (divided in the three above classes of composite fillers, bio-matrices, and materials for construction) is to define their potential for reducing their environmental impact. A significant aspect in terms of LCA of biomass for application in materials, as evidenced in a study over their use in the packaging context, is their traceability [174]. This can be explained by some life cycle assessment (LCA) studies reported on various cultivation systems, as far as seeds are regarded, and the potential role of materials from waste into them. It is worth noting that incineration that is mostly dedicated to seed nuts, including detailed studies, are, e.g., dedicated to pistachio [175], which indicated that, for 1 kg of biochar, emissions of CO₂ and CH₄ were 1180 and 4 g, respectively. Other than this, the production of biodiesel can also be considered an alternative scenario. However, this does not imply that the yield of this production is necessarily high: one of the most diffuse cases, as is based on a non-food seed, is the use of jatropha, where the oil extracted from the seed was reported to be variable (between 21 and 48%) across the regions of India, which does not represent more than 40% of their relative weight [176]. This would suggest, given the amount of biomass remaining, a potential use of oil seed cake, which is scantily exploited and whose position in the LCA system is defined in Figure 13, where no mention of possible materials' use is listed. In the case of biodiesel production from Jatropha in Pakistan, by-products, including glycerin (for cosmetics or medical application) and press cake, are mentioned instead, although for press cake, only food for fishes and organic fertilizer (bio-compost) application have been identified [177].

The issue highlighted in Figure 13 can be also reported in other cases for seed production systems; the potential application of discarded seeds or of post-extraction remaining seeds for biodiesel production is not contemplated as a potential option, despite the unavoidable generation of seed-based waste from the process. In particular, some studies are mentioned on LCA of some systems based on seed use for food purposes. Examples include hemp [178], where consideration has been mainly limited to fibers so far, and food use is a recent occurrence, still not involving questions about the use of generated refuse. However, the development of hemp oil-based bio-resins [179] points towards the possible use of seed in this context. In other cases, for larger and more ligneous seeds, such as apricots, whose use has been proposed for biodiesel extraction, issues are encountered in the process, which suggested the fabrication of innovative catalysts for the purpose, in the specific case based on cerium oxide [180]. Other than biodiesel, other extractions are considered with more focused (species-dependent) application: this is the case for

cucurbitin, a biologically active non-proteic amino-acid used for antiparasitic purposes, extracted from pumpkin seeds [181]. A more general analysis has been also carried out on LCA of date palm seeds, yet they are intended on germination [182].

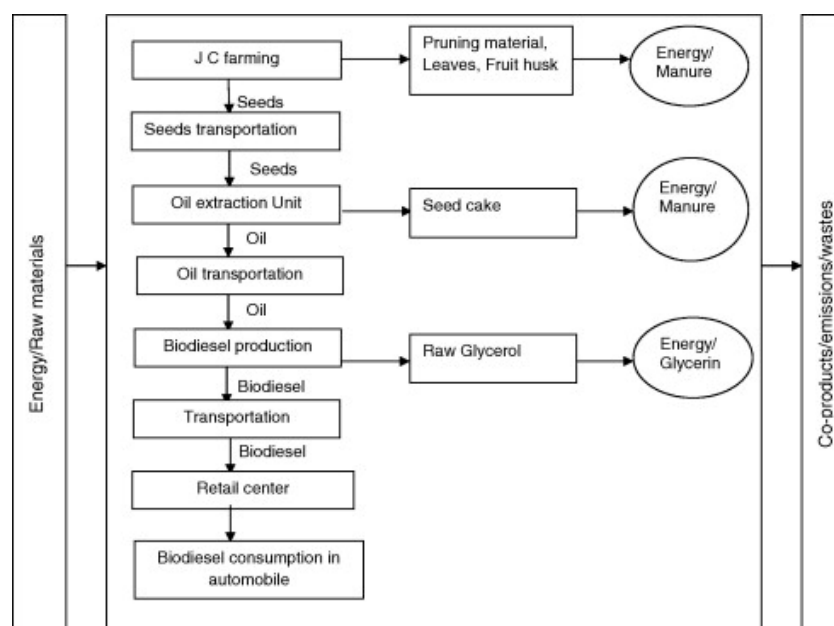


Figure 13. LCA system for the jatropha bio-diesel production in India [176].

It is possibly fair to say that LCA studies on seed-based systems do either not contemplate the use of seed cake in materials (not to say the bare seeds) or describe it as far away from the field of composites or relevant matrices. This appears as a significant limitation for the possible environmental assessment of the process, which this study intends to single out, as much as possible.

5. Applicability

Despite all the above limitations, several applications are currently investigated in the field of seed-based composites and matrices, mostly but not exclusively linked to wood replacement ones. In some cases, to ensure a higher flexibility for use, the production of hybrids, including different fillers, can also be proposed. In view of this solution, the comparison of a number of these needs to be performed. In Ref. [183], three not very studied, but quite diffused, seed fillers were, e.g., compared, namely from soap nuts, bael (*Aegle marmelos*), and black myrobalan (*Terminalia chebula*), structurally and dimensionally different. Another field that indicated a considerable promise for the use of waste seeds is the one of tribological applications, where the substitution of traditional materials, such as, for example, carbon black, for polymer filling, especially in the case of rubber, is intensely sought for [184]. This is the case for instance for the introduction of *Jatropha curcas* seeds into epoxy resin [185].

However, overtime, the field has been expanding towards other aspects more loosely related to it, moving rather towards other functionalities more connected with the geometry, structure, and material characteristics of the seed, which is no longer identified as a bare filler. This is the case for Ref. [186], where a composite including seed from *Nigella sativa* served in a nanohybrid form for the removal of methylene blue, which was intended at evaluating its more general viability in terms of water treatment functioning. Other antibacterial applications, focused on water treatment applications, were offered again by seed from *Nigella Sativa*, which is reported in a review that included many different seeds for the immobilization of various heavy metal particles [187].

Chemical removal, and in a wider sense decontamination, is another possibility for seed-based fillers; in particular, starting from the evidence of orange waste to facilitate

the treatment of sewage, Ref. [188] suggested the potential of orange seed powder, made conductive with magnetite (Fe_3O_4) coating, in the removal of methylene blue and violent dyes [189]. A similar application, more focused also on the possibility to treat biomedical refuse, hence involving also water polluted, other than again with methylene blue as a comparative agent, also with drugs (ibuprofen), was also proposed dealing with hemp seed composites [190]. Another field in which the presence of seeds in the composite does produce distinct potential is the production of antibacterial films, namely for the ability to ensure sufficient strengthening and consistency to biodegradable polymer gels, such as it is the case for chitosan in the immobilization of zinc oxide [191]. The potential reduction of date seed powder (and to other sufficiently ligneous seed powder, potentially) to the nanometric size would also open other fields of application, such as, for example, the filling of dental materials and resins, such as poly(methylmetacrylate) [192]. This is also reported here for desired completeness.

6. Conclusions

The application of seeds in composites, as the filler or else as the matrix, would provide a prospective use in terms of circular economy and sustainability to this abundant waste, often derived from very large productive systems, deeply branched also in other sectors, such as food production or fuel oil extraction. Criticalities might be encountered in evaluating in which form the seed-originating material can be employed, either as such or in the form of powder, cake, pellets, etc.

The factors involved are multifold, from granulometry to the mechanical performance of the original seed. This has not only importance in terms of mechanical and structural performance, but also as far as added value is regarded, and has an influence on its real integration into a circular economy paradigm. In this sense, the competition of seed-derived waste for use in materials with other sectors involving an application with a lower hierarchy level as regards EC directive 2008/98, namely incineration (for active carbons or biochar production) or biodiesel development is still open, until suitable applications of these in materials recycling are elicited. It is not by chance therefore that the most considered seeds are, other than those that are part of a large food productive system (e.g., olive, orange, nuts), also some that are specifically aimed for incineration (date palm), or for biodiesel production (jatropha). Life cycle assessment studies seldom recognize any role to waste seed and even not to seed cake post-extraction, which appears as an obvious delaying factor for their process of use under circular economy auspices.

Further considerations would also concern the possible integration of other knowledge into seed-derived composites, as regards the treatment of material to ensure improved compatibility with polymer matrices, and the possible combined use together with seed-extracted starch biopolymers, possibly and ideally originated from the same cultivation.

Author Contributions: The authors C.F., F.V.d.C. and C.S. equally contributed to the design and implementation of the research, to the analysis of the results and to the writing of the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: This research was co-funded by the Ministry of Foreign Affairs and International Cooperation of Italy, and by the Ministry of Education, Science, Culture and Sports of Montenegro, as part of the bilateral Science and Technology Cooperation Program 2022–2024 entitled ‘SEA-COMP, Sea Waste from Adriatic to Enhance Marine Composites’ project activity.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: No new data were created or analyzed in this study. Data sharing is not applicable to this article.

Acknowledgments: The authors gratefully acknowledge the Faculty of Maritime Engineering of the University of Montenegro, and in particular the Dean Danilo Nikolic for the fruitful discussions on the issue of recovering waste biomass materials in a circular economy context.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Hammajam Alhaji, A.; Ismarrubie Zahari, N.; Sapuan Mohd, S. Review of agro waste plastic composites production. *J. Min. Mater. Character. Eng.* **2013**, *1*, 37218.
2. De Paola, S.; Minak, G.; Fragassa, C.; Pavlovic, A. Green Composites: A Review of State of Art. In Proceedings of the 30th DANUBIA-ADRIA Symposium on Advances in Experimental Mechanics, DAS 2013 Proceedings, Primosten, Croatia, 25–28 September 2013; pp. 77–78.
3. Puglia, D.; Sarasini, F.; Santulli, C.; Kenny, J.M. Manufacturing of natural fiber/agrowaste based polymer composites. In *Green Biocomposites: Manufacturing and Properties*; Jawaid, M., Sapuan, S.M., Alothman, O.Y., Eds.; Springer: Cham, Switzerland, 2017; pp. 125–147.
4. Pao, C.N.Z.; Yeng, C.M. Properties and characterization of wood plastic composites made from agro-waste materials and post-used expanded polyester foam. *J. Thermoplast. Compos. Mater.* **2019**, *32*, 951–966. [\[CrossRef\]](#)
5. Santulli, C. Utilization of Renewable Biomass and Waste Materials for Production of Environmentally-Friendly, Bio-based Composites. In *Eco-Friendly Adhesives for Wood and Natural Fiber Composites: Characterization, Fabrication and Applications*; Jawaid, M., Khan, T.A., Nasir, M., Asim, M., Eds.; Springer: Cham, Switzerland, 2021; pp. 131–145.
6. Saavedra, I.R.L.; Miguel, J.J.O.; Castañeda-Olivera, C.A.; Galván, J.J.O.; Alfaro, E.B. Biochar from Residual Lignocellulosic Biomass for the Cultivation of Prosopis Limensis. *Chem. Eng. Trans.* **2022**, *92*, 223–228.
7. Skodras, G.; Diamantopoulou, I.; Zabanitoutou, A.; Stavropoulos, G.; Sakellaropoulos, G.P. Enhanced mercury adsorption in activated carbons from biomass materials and waste tires. *Fuel Process Technol.* **2007**, *88*, 749–758. [\[CrossRef\]](#)
8. Stavropoulos, G.G.; Zabanitoutou, A.A. Production and characterization of activated carbons from olive-seed waste residue. *Micropor. Mesopor. Mater.* **2005**, *82*, 79–85. [\[CrossRef\]](#)
9. Ghosh, S.; Nandasana, M.; Webster, T.J.; Thongmee, S. Agrowaste-generated biochar for the sustainable remediation of refractory pollutants. *Front. Chem.* **2023**, *11*, 1266556. [\[CrossRef\]](#)
10. Cruz, G.J.; Mondal, D.; Rimaycuna, J.; Soukup, K.; Gómez, M.M.; Solis, J.L.; Lang, J. Agrowaste derived biochars impregnated with ZnO for removal of arsenic and lead in water. *J. Environ. Chem. Eng.* **2020**, *8*, 103800. [\[CrossRef\]](#)
11. Kadhom, M.; Albayati, N.; Alalwan, H.; Al-Furaiji, M. Removal of dyes by agricultural waste. *Sustain. Chem. Pharm.* **2020**, *16*, 100259. [\[CrossRef\]](#)
12. Khee, Y.L.; Kiew, P.L.; Chung, Y.T. Valorizing papaya seed waste for wastewater treatment: A review. *Int. J. Environ. Sci. Technol.* **2023**, *20*, 2327–2346. [\[CrossRef\]](#)
13. Reddy, M.S.; Sivaramakrishna, L.; Reddy, A.V. The use of an agricultural waste material, Jujuba seeds for the removal of anionic dye (Congo red) from aqueous medium. *J. Hazard. Mater.* **2012**, *203*, 118–127. [\[CrossRef\]](#)
14. Inayat, A.; Jamil, F.; Ghenai, C.; Kamil, M.; Bokhari, A.; Waris, A.; Rafiq, S.; Khurram, S. Biodiesel synthesis from neem oil using neem seeds residue as sustainable catalyst support. *Biomass Convers. Biorefinery* **2021**, 1–6. [\[CrossRef\]](#)
15. Coelho, J.P.; Filipe, R.M.; Robalo, M.P.; Stateva, R.P. Recovering value from organic waste materials: Supercritical fluid extraction of oil from industrial grape seeds. *J. Supercrit. Fluids* **2018**, *141*, 68–77. [\[CrossRef\]](#)
16. Sydow, Z.; Sydow, M.; Wojciechowski, Ł.; Bieńczyk, K. Tribological performance of composites reinforced with the agricultural, industrial and post-consumer wastes: A review. *Materials* **2021**, *14*, 1863. [\[CrossRef\]](#)
17. Sydow, Z.; Bula, K.; Gapiński, B. Friction and wear of polypropylene-based composites reinforced with cherry seed powder. *Trib. Int.* **2023**, *179*, 108177.
18. Ige, O.E.; Inambao, L.F.; Adewumi, A.G. Biomass-based composites for brake pads: A review. *Int. J. Mech. Eng. Technol.* **2019**, *10*, 920–943.
19. Ammar, Z.; Ibrahim, H.; Adly, M.; Sarris, I.; Mehanny, S. Influence of natural fiber content on the frictional material of brake pads—A review. *J. Compos. Sci.* **2023**, *7*, 72. [\[CrossRef\]](#)
20. Ajibade, O.A.; Agunsoye, J.O.; Oke, S.A. A wear rate model incorporating inflationary cost of agro-waste filled composites for brake pad applications to lower composite cost. *SN Appl. Sci.* **2021**, *3*, 1–21. [\[CrossRef\]](#)
21. Balart, R.; Montanes, N.; Dominici, F.; Boronat, T.; Torres-Giner, S. Environmentally friendly polymers and polymer composites. *Materials* **2020**, *13*, 4892. [\[CrossRef\]](#)
22. Cabrera, F.C. Eco-friendly polymer composites: A review of suitable methods for waste management. *Polym. Compos.* **2021**, *42*, 2653–2677. [\[CrossRef\]](#)
23. Lucarini, M.; Durazzo, A.; Romani, A.; Campo, M.; Lombardi-Boccia, G.; Cecchini, F. Bio-based compounds from grape seeds: A biorefinery approach. *Molecules* **2018**, *23*, 1888. [\[CrossRef\]](#)
24. Mohite, A.S.; Jagtap, A.R.; Avhad, M.S.; More, A.P. Recycling of major agriculture crop residues and its application in polymer industry: A Review in the context of waste to energy nexus. *Energy Nexus* **2022**, *7*, 100134. [\[CrossRef\]](#)
25. ASTM D790-17; Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials. ASTM: West Conshohocken, PA, USA, 2017.
26. ASTM D638-22; Standard Test Method for Tensile Properties of Plastics. ASTM: West Conshohocken, PA, USA, 2022.
27. Dattu, V.S.C.; Lokesh, M.; Kumar, A.; Rajkumar, M.; Vallavi, M.A.; Britto, A.S.F. Mechanical characterization of polymer composite reinforced with bio-fillers. *Mater. Today Proc.* **2022**, *69*, 695–699. [\[CrossRef\]](#)

28. Naik, S.; Halemani, B.; Raju, G.U. Investigation of the mechanical properties of tamarind seed particles reinforced epoxy composites. In *AIP Conference Proceedings*; AIP Publishing: College Park, MD, USA, 2019; Volume 2057.
29. ISO, 179; Plastics. Determination of Charpy Impact Strength. ISO: Geneva, Switzerland, 1997.
30. Voicu, G.; Tudosie, E.M.; Ungureanu, N.; Constantin, G.A. Some mechanical characteristics of wheat seeds obtained by uniaxial compression tests. *Univ. Politeh. Buch. Sci. Bull. D* **2013**, *75*, 265–278.
31. Zarei, A.; Zamani, Z.; Fatahi, R.; Mousavi, A.; Salami, S.A. A mechanical method of determining seed-hardness in pomegranate. *J. Crop Improv.* **2013**, *27*, 444–459. [[CrossRef](#)]
32. Jafari, S.; Khazaei, J.; Arabhosseini, A.; Massah, J.; Khoshtaghaza, M.H. Study on mechanical properties of sunflower seeds. *Electron. J. Pol. Agric. Univ.* **2011**, *14*, 6.
33. Izli, N.; Unal, H.; Sincik, M. Physical and mechanical properties of rapeseed at different moisture content. *Int. Agrophys* **2009**, *23*, 137–145.
34. Bastos, A.C.; Ferraz, A.C.D.O. Mechanical properties of castor beans subject to different drying temperatures aiming to disrupt the bean coat. *Eng. Agrícola* **2014**, *34*, 93–101. [[CrossRef](#)]
35. Yang, L.; Chen, H.; Xiao, J.; Fan, Y.; Song, S.; Zhang, Y.; Liu, X. Research on Structural–Mechanical Properties during the Castor Episperme Breaking Process. *Processes* **2021**, *9*, 1777. [[CrossRef](#)]
36. Arrakhiz, F.Z.; Benmoussa, K.; Bouhfid, R.; Qaiss, A. Pine cone fiber/clay hybrid composite: Mechanical and thermal properties. *Mater. Des.* **2013**, *50*, 376–381. [[CrossRef](#)]
37. Summerscales, J.; Dissanayake, N.P. Allocation in the life cycle assessment (LCA) of flax fibres for the reinforcement of composites. In *Advances in Natural Fibre Composites: Raw Materials, Processing and Analysis*; Springer International Publishing: Berlin/Heidelberg, Germany, 2018; pp. 223–235.
38. Sirisomboon, P.; Kitchaiya, P.; Pholpho, T.; Mahuttanyavanitch, W. Physical and mechanical properties of *Jatropha curcas* L. fruits, nuts and kernels. *Biosyst. Eng.* **2007**, *97*, 201–207. [[CrossRef](#)]
39. Ala'a, H.; Osman, A.I.; Jamil, F.; Mehta, N.; Al-Haj, L.; Coulon, F.; Al-Maawali, S.; Al Nabhani, A.; Kyaw, H.H.; Rooney, D.W.; et al. Integrating life cycle assessment and characterisation techniques: A case study of biodiesel production utilising waste *Prunus Armeniaca* seeds (PAS) and a novel catalyst. *J. Environ. Manag.* **2022**, *304*, 114319.
40. Altuntas, E.; Erkol, M. The effects of moisture content, compression speeds, and axes on mechanical properties of walnut cultivars. *Food Bioproc. Technol.* **2011**, *4*, 1288–1295. [[CrossRef](#)]
41. Henrique, M.A.; Silvério, H.A.; Neto, W.P.F.; Pasquini, D. Valorization of an agro-industrial waste, mango seed, by the extraction and characterization of its cellulose nanocrystals. *J. Environ. Manag.* **2013**, *121*, 202–209. [[CrossRef](#)] [[PubMed](#)]
42. García-Mahecha, M.; Soto-Valdez, H.; Peralta, E.; Carvajal-Millan, E.; Madera-Santana, T.J.; Lomeli-Ramírez, M.G.; Colín-Chávez, C. Production and Characterization of Cellulosic Pulp from Mango Agro-Industrial Waste and Potential Applications. *Polymers* **2023**, *15*, 3163. [[CrossRef](#)] [[PubMed](#)]
43. Rahman, M.M.; Ho, K.; Netravali, A.N. Bio-based polymeric resin from agricultural waste, neem (*Azadirachta indica*) seed cake, for green composites. *J. Appl. Polym. Sci.* **2015**, *132*. [[CrossRef](#)]
44. Rahman, M.M.; Netravali, A.N. Green resin from forestry waste residue “Karanja (*Pongamia pinnata*) seed cake” for biobased composite structures. *ACS Sustain. Chem. Eng.* **2014**, *2*, 2318–2328. [[CrossRef](#)]
45. Shivamurthy, B.; Murthy, K.; Joseph, P.C.; Rishi, K.; Bhat, K.U.; Anandhan, S. Mechanical properties and sliding wear behavior of jatropha seed cake waste/epoxy composites. *J. Mater. Cycles Waste Manag.* **2015**, *17*, 144–156. [[CrossRef](#)]
46. Fu, D.; Netravali, A.N. Green composites based on avocado seed starch and nano-and micro-scale cellulose. *Polym. Compos.* **2020**, *41*, 4631–4648. [[CrossRef](#)]
47. Garba, Z.N.; Rahim, A.A.; Bello, B.Z. Optimization of preparation conditions for activated carbon from *Brachystegia eurycoma* seed hulls: A new precursor using central composite design. *J. Environ. Chem. Eng.* **2015**, *3*, 2892–2899. [[CrossRef](#)]
48. Garba, Z.N.; Rahim, A.A. Adsorption of 4-chlorophenol onto optimum activated carbon from an agricultural waste. *Int. J. Sci. Res.* **2015**, *4*, 1931–1936.
49. Neme, I.; Gonfa, G.; Masi, C. Preparation and characterization of activated carbon from castor seed hull by chemical activation with H₃PO₄. *Results Mater.* **2022**, *15*, 100304. [[CrossRef](#)]
50. De' Nobili, M.D.; Bernhardt, D.C.; Basanta, M.F.; Rojas, A.M. Sunflower (*Helianthus annuus* L.) seed hull waste: Composition, antioxidant activity, and filler performance in pectin-based film composites. *Front. Nutr.* **2021**, *8*, 777214. [[CrossRef](#)]
51. Hameed, B.H.; El-Khaiary, M.I. Removal of basic dye from aqueous medium using a novel agricultural waste material: Pumpkin seed hull. *J. Hazard. Mater.* **2008**, *155*, 601–609. [[CrossRef](#)]
52. Lima, E.M.B.; Middea, A.; Neumann, R.; Thiré, R.M.D.S.M.; Pereira, J.F.; de Freitas, S.C.; Penteado, M.S.; Lima, A.M.; Minguita, A.P.D.S.; Corrêa, A.C.; et al. Biocomposites of PLA and mango seed waste: Potential material for food packaging and a technological alternative to reduce environmental impact. *Starch-Stärke* **2021**, *73*, 2000118. [[CrossRef](#)]
53. Gomez-Caturla, J.; Lascano, D.; Montanes, N.; Balart, R.; Dominici, F.; Puglia, D.; Torre, L. Manufacturing and characterization of highly environmentally-friendly composites with polylactide matrix and mango kernel seed flour. *Expr. Polym. Lett.* **2023**, *17*, 334. [[CrossRef](#)]
54. Ameh, A.O.; Isa, M.T.; Sanusi, I. Effect of particle size and concentration on the mechanical properties of polyester/date palm seed particulate composites. *Leon Electron. J. Pract. Technol.* **2015**, *14*, 65–78.

55. Elkhoully, H.I.; Abdel-Magied, R.K.; Aly, M.F. Date palm seed as suitable filler material in glass–epoxy composites. *Iran. Polym. J.* **2019**, *28*, 65–73. [\[CrossRef\]](#)
56. Kuram, E. Rheological, mechanical and morphological properties of acrylonitrile butadiene styrene composite filled with sunflower seed (*Helianthus annuus* L.) husk flour. *J. Polym. Res.* **2020**, *27*, 219. [\[CrossRef\]](#)
57. Ławińska, K. Production of Agglomerates, Composite Materials, and Seed Coatings from Tannery Waste as New Methods for Its Management. *Materials* **2021**, *14*, 6695. [\[CrossRef\]](#)
58. Pompei, S.; Tirillò, J.; Sarasini, F.; Santulli, C. Development of Thermoplastic Starch (TPS) Including Leather Waste Fragments. *Polymers* **2020**, *12*, 1811. [\[CrossRef\]](#) [\[PubMed\]](#)
59. Zdanowska, P.; Florczak, I.; Słoma, J.; Tucki, K.; Orynycz, O.; Wasiak, A.; Świć, A. An evaluation of the quality and microstructure of biodegradable composites as contribution towards better management of food industry wastes. *Sustainability* **2019**, *11*, 1504. [\[CrossRef\]](#)
60. Golshan Tafti, A.; Solaimani Dahdivan, N.; Yasini Ardakani, S.A. Physicochemical properties and applications of date seed and its oil. *Int. Food Res. J.* **2017**, *24*, 1399–1406.
61. Fikry, M.; Yusof, Y.A.; Al-Awaadh, A.M.; Rahman, R.A.; Chin, N.L.; Mousa, E.; Chang, L.S. Effect of the roasting conditions on the physicochemical, quality and sensory attributes of coffee-like powder and brew from defatted palm date seeds. *Foods* **2019**, *8*, 61. [\[CrossRef\]](#)
62. Venkatachalam, C.D.; Sengottian, M. Study on roasted date seed non caffeinated Coffee powder as a promising alternative. *Asian J. Res. Soc. Sci. Humanit.* **2016**, *6*, 1387–1394. [\[CrossRef\]](#)
63. Terral, J.F.; Newton, C.; Ivorra, S.; Gros-Balthazard, M.; de Moraes, C.T.; Picq, S.; Tengberg, M.; Pintaud, J.C. Insights into the historical biogeography of the date palm (*Phoenix dactylifera* L.) using geometric morphometry of modern and ancient seeds. *J. Biogeogr.* **2012**, *39*, 929–941. [\[CrossRef\]](#)
64. Ajuria, J.; Redondo, E.; Arnaiz, M.; Mysyk, R.; Rojo, T.; Goikolea, E. Lithium and sodium ion capacitors with high energy and power densities based on carbons from recycled olive pits. *J. Power Sources* **2017**, *359*, 17–26. [\[CrossRef\]](#)
65. Celik, H.; Nadaroglu, H.; Senol, M. Evaluation of antioxidant, antiradical and antimicrobial activities of olive pits (*Olea europaea* L.). *Bulg. J. Agric. Sci.* **2014**, *20*, 1392–1400.
66. Kumari, N.; Kumar, M.; Puri, S.; Baohong, Z.; Rais, N.; Pundir, A.; Chandran, D.; Raman, P.; Dhumal, S.; Lorenzo, J.M. Peach (*Prunus persica* (L.) Batsch) seeds and kernels as potential plant-based functional food ingredients: A review of bioactive compounds and health-promoting activities. *Food Biosci.* **2023**, *54*, 102914. [\[CrossRef\]](#)
67. Grubeša, I.N.; Marković, B.; Nyarko, M.H.; Krstić, H.; Brdarić, J.; Filipović, N.; Szenti, I.; Kukovecz, Á. Potential of fruit pits as aggregate in concrete. *Constr. Build. Mater.* **2022**, *345*, 128366. [\[CrossRef\]](#)
68. Hernández-Rentero, C.; Córdoba, R.; Moreno, N.; Caballero, A.; Morales, J.; Olivares-Marín, M.; Gómez-Serrano, V. Low-cost disordered carbons for Li/S batteries: A high-performance carbon with dual porosity derived from cherry pits. *Nano Res.* **2018**, *11*, 89–100. [\[CrossRef\]](#)
69. Benhamou, A.A.; Kassab, Z.; Boussetta, A.; Salim, M.H.; Ablouh, E.H.; Nadifiyine, M.; Moubarik, A.; El Achaby, M. Beneficiation of cactus fruit waste seeds for the production of cellulose nanostructures: Extraction and properties. *Int. J. Biol. Macromol.* **2022**, *203*, 302–311. [\[CrossRef\]](#)
70. Al-Wandawi, H.; Abdul-Rahman, M.; Al-Shaikhly, K. Tomato processing wastes as essential raw materials source. *J. Agric. Food Chem.* **1985**, *33*, 804–807. [\[CrossRef\]](#)
71. Schettini, E.; Santagata, G.; Malinconico, M.; Immirzi, B.; Mugnozza, G.S.; Vox, G. Recycled wastes of tomato and hemp fibres for biodegradable pots: Physico-chemical characterization and field performance. *Resour. Conserv. Recycl.* **2013**, *70*, 9–19. [\[CrossRef\]](#)
72. Jeguirim, S.E. Tomato wastes valorization for bio-based materials production. In *Tomato Processing By-Products*; Jeguirim, M., Zorpas, A., Eds.; Academic Press: Cambridge, MA, USA, 2022; pp. 149–170.
73. Brinker, F. Prickly pear as food and medicine. *J. Diet. Suppl.* **2009**, *6*, 362–376. [\[CrossRef\]](#)
74. Sawaya, W.N.; Khan, P. Chemical characterization of prickly pear seed oil, *Opuntia ficus-indica*. *J. Food Sci.* **1982**, *47*, 2060–2061. [\[CrossRef\]](#)
75. Ennouri, M.; Evelyne, B.; Laurence, M.; Hamadi, A. Fatty acid composition and rheological behaviour of prickly pear seed oils. *Food Chem.* **2005**, *93*, 431–437. [\[CrossRef\]](#)
76. Karabagias, V.K.; Karabagias, I.K.; Gatzias, I.; Badeka, A.V. Prickly pear seed oil by shelf-grown cactus fruits: Waste or maste? *Processes* **2020**, *8*, 132. [\[CrossRef\]](#)
77. Kammoun, Z.; Trabelsi, A. Development of lightweight concrete using prickly pear fibres. *Constr. Build. Mater.* **2019**, *210*, 269–277. [\[CrossRef\]](#)
78. El-Gendi, H.; Salama, A.; El-Fakharany, E.M.; Saleh, A.K. Optimization of bacterial cellulose production from prickly pear peels and its ex situ impregnation with fruit byproducts for antimicrobial and strawberry packaging applications. *Carbohydr. Polym.* **2023**, *302*, 120383. [\[CrossRef\]](#)
79. Hernández-Carranza, P.; Rivadeneyra-Mata, M.; Ramos-Cassellis, M.E.; Aparicio-Fernández, X.; Navarro-Cruz, A.R.; Ávila-Sosa, R.; Ochoa-Velasco, C.E. Characterization of red prickly pear peel (*Opuntia ficus-indica* L.) and its mucilage obtained by traditional and novel methodologies. *J. Food Meas. Charact.* **2019**, *13*, 1111–1119. [\[CrossRef\]](#)
80. Bagula, M.; Arya, S.S. Tamarind seeds: Chemistry, technology, applications and health benefits: A review. *Seed* **1998**, *70*, 25–35.

81. Nayak, A.K.; Pal, D. Development of pH-sensitive tamarind seed polysaccharide–alginate composite beads for controlled diclofenac sodium delivery using response surface methodology. *Int. J. Biol. Macromol.* **2011**, *49*, 784–793. [[CrossRef](#)] [[PubMed](#)]
82. Balasundar, P.; Narayanasamy, P.; Senthil, S.; Al-Dhabi, N.A.; Prithivirajan, R.; Kumar, R.S.; Ramkumar, T.; Bhat, K.S. Physico-chemical study of pistachio (*Pistacia vera*) nutshell particles as a bio-filler for eco-friendly composites. *Mater. Res. Expr.* **2019**, *6*, 105339. [[CrossRef](#)]
83. Salazar-Cruz, B.A.; Chávez-Cinco, M.Y.; Morales-Cepeda, A.B.; Ramos-Galván, C.E.; Rivera-Armenta, J.L. Evaluation of thermal properties of composites prepared from pistachio shell particles treated chemically and polypropylene. *Molecules* **2022**, *27*, 426. [[CrossRef](#)] [[PubMed](#)]
84. Geneau-Sbartai, C.; Leyris, J.; Silvestre, F.; Rigal, L. Sunflower cake as a natural composite: Composition and plastic properties. *J. Agric. Food Chem.* **2008**, *56*, 11198–11208. [[CrossRef](#)] [[PubMed](#)]
85. Hosseini, A.R.; Zahabi, N. Fabrication and rheological properties of a novel interpenetrating network hydrogel based on sage seed hydrocolloid and globulin from the hydrocolloid extraction by-product. *Int. J. Biol. Macromol.* **2023**, *253*, 127452. [[CrossRef](#)]
86. Ayırlmis, N.; Kaymakci, A.; Ozdemir, F. Sunflower seed cake as reinforcing filler in thermoplastic composites. *J. Appl. Polym. Sci.* **2013**, *129*, 1170–1178. [[CrossRef](#)]
87. Babić, L.J.; Radojčin, M.; Pavkov, I.; Babić, M.; Turan, J.; Zoranovia, M.; Stanišić, S. Physical properties and compression loading behaviour of corn seed. *Int. Agrophys* **2013**, *27*, 119–126. [[CrossRef](#)]
88. Baümler, E.; Cuniberti, A.; Nolasco, S.M.; Riccobene, I.C. Moisture dependent physical and compression properties of safflower seed. *J. Food Eng.* **2006**, *72*, 134–140. [[CrossRef](#)]
89. Singh, K.K.; Goswami, T.K. Mechanical properties of cumin seed (*Cuminum cyminum* Linn.) under compressive loading. *J. Food Eng.* **1998**, *36*, 311–321. [[CrossRef](#)]
90. Olukayode, O.; Alade, E.I.; Oyelami, S. Effect of moisture contents and compression axes on some physical and mechanical properties of *Dioclea reflexa* seed. *J. Appl. Life Sci. Environ.* **2022**, *55*, 189–200. [[CrossRef](#)]
91. Shashikumar, C.; Pradhan, R.C.; Mishra, S. Influence of moisture content and compression axis on physico-mechanical properties of *Shorea robusta* seeds. *J. Inst. Eng. (India) A* **2018**, *99*, 279–286. [[CrossRef](#)]
92. Shreelavaniya, R.; Kamaraj, S. Effect of moisture content on physical properties of black pepper. *Int. J. Curr. Microbiol. Appl. Sci.* **2017**, *6*, 4873–4879. [[CrossRef](#)]
93. Liu, Y.; Lyu, L.; Guo, J.; Wang, Y. Sound absorption performance of the poplar seed Fiber/PCL composite materials. *Materials* **2020**, *13*, 1465. [[CrossRef](#)] [[PubMed](#)]
94. Shokir, A.; Avazbek, O.; Olimjon, S. Research of Separation of Industrial Fiber from Cotton Waste. *Des. Eng.* **2021**, *9*, 11442–11453.
95. Baker, R.V.; Anthony, W.S.; Sutton, R.M. Seed cotton cleaning and extracting. *Cotton Ginners Handb. Agric. Handb.* **1994**, *503*, 69–89.
96. Zheng, Y.; Wang, A. Kapok fiber: Applications. In *Biomass and Bioenergy: Applications*; Hakeem, K.R., Jawaid, M., Rashid, U., Eds.; Springer: Berlin/Heidelberg, Germany, 2014; pp. 251–266.
97. Mohan Kumar, K.; Naik, V.; Waddar, S.S.; Santhosh, N.; Kaup, V.; Harish, H.V. Mechanical and water absorption characterization of mango seed shell/epoxy composite for low load carrying structures. *Int. J. Polym. Sci.* **2023**, *2023*, 9976409. [[CrossRef](#)]
98. Abd Mohammed, A. Study the thermal properties and water absorption of composite materials reinforced with date and olive seeds. *Iraqi J. Mech. Mater. Eng.* **2015**, *15*, 138–152.
99. Elkhouly, H.I.; Abdel-Magied, R.K.M.; Aly, M.F. An investigation of date palm seed as effective filler material of glass–epoxy composites using optimization techniques. *Polym. Polym. Compos.* **2020**, *28*, 541–553. [[CrossRef](#)]
100. Nagaraj, N.; Balasubramaniam, S.; Venkataraman, V.; Manickam, R.; Nagarajan, R.; Oluwarotimi, I.S. Effect of cellulosic filler loading on mechanical and thermal properties of date palm seed/vinyl ester composites. *Int. J. Biol. Macromol.* **2020**, *147*, 53–66. [[CrossRef](#)]
101. Murawski, A.; Diaz, R.; Inglesby, S.; Delabar, K.; Quirino, R.L. Synthesis of bio-based polymer composites: Fabrication, fillers, properties, and challenges. In *Polymer Nanocomposites in Biomedical Engineering*; Sadasivunim, K.K., Ponnammam, D., Rajan, M., Ahmed, B., Ali, M., Al-Maadeed, S.A., Eds.; Springer: Cham, Switzerland, 2019; pp. 29–55.
102. Bodîrlău, R.; Teacă, C.A.; Spiridon, I. Green composites comprising thermoplastic corn starch and various cellulose-based fillers. *BioResources* **2014**, *9*, 39–53. [[CrossRef](#)]
103. Abu-Jdayil, B.; Hittini, W.; Mourad, A.H. Development of date pit–polystyrene thermoplastic heat insulator material: Physical and thermal properties. *Int. J. Polym. Sci.* **2019**, *2019*, 1697627. [[CrossRef](#)]
104. Mittal, V.; Luckachan, G.E.; Chernev, B.; Matsko, N.B. Bio-polyester–date seed powder composites: Morphology and component migration. *Polym. Eng. Sci.* **2015**, *55*, 877–888. [[CrossRef](#)]
105. Muniyadi, M.; Ng, T.Y.S.; Munusamy, Y.; Ooi, Z.X. Mimulus elengi seed Shell powder as a new bio-filler for polypropylene-based bio-composites. *BioResource* **2018**, *13*, 272–289. [[CrossRef](#)]
106. Appu, S.P.; Ashwaq, O.; Al-Harthi, M.; Umar, Y. Fabrication and characterization of composites from recycled polyethylene and date palm seed powder. *J. Thermoplast. Compos. Mater.* **2021**, *34*, 316–327. [[CrossRef](#)]
107. Mazzanti, V.; Malagutti, L.; Mollica, F. FDM 3D printing of polymers containing natural fillers: A review of their mechanical properties. *Polymers* **2019**, *11*, 1094. [[CrossRef](#)]
108. Karunakaran, K.; Pugazhenth, R.; Anbuezhhiyan, G.; Saravanan, R.; Reddy, M.V. Experimental investigations on synthesis and characterization of tamarind seed powder reinforced bio-composites. *Mater. Today Proc.* **2022**, *64*, 760–764. [[CrossRef](#)]

109. Nagarjun, J.; Kanchana, J.; Rajeshkumar, G.; Anto Dilip, A. Enhanced mechanical characteristics of polylactic acid/tamarind kernel filler green composite filament for 3D printing. *Polym. Compos.* **2023**, *44*, 7925–7940. [\[CrossRef\]](#)
110. Scaffaro, R.; Citarrella, M.C.; Morreale, M. Green Composites Based on Mater-Bi® and Solanum lycopersicum Plant Waste for 3D Printing Applications. *Polymers* **2023**, *15*, 325. [\[CrossRef\]](#)
111. Zineh, B.R.; Roshangar, L. An experimental study on the mechanical and biological properties of bio-printed alginate/halloysite nanotube/methylcellulose/Russian olive-based scaffolds. *Adv. Pharm. Bull.* **2018**, *8*, 643. [\[CrossRef\]](#)
112. Mohanty, A.K.; Vivekanandhan, S.; Pin, J.M.; Misra, M. Composites from renewable and sustainable resources: Challenges and innovations. *Science* **2018**, *362*, 536–542. [\[CrossRef\]](#)
113. Nagaprasad, N.; Stalin, B.; Vignesh, V.; Ravichandran, M.; Rajini, N.; Ismail, S.O. Applicability of cellulosic-based *Polyalthia longigolia* seed filler reinforced vinyl ester biocomposites on tribological performance. *Polym. Compos.* **2021**, *42*, 791–804. [\[CrossRef\]](#)
114. Samanth, M.; Bhat, K.S. Conventional and unconventional chemical treatment methods of natural fibres for sustainable biocomposites. *Sustain. Chem. Clim. Action.* **2023**, *3*, 100034. [\[CrossRef\]](#)
115. Moad, G.; Solomon, D.H. The critical importance of adopting whole-of-life strategies for polymers and plastics. *Sustainability* **2021**, *13*, 8218. [\[CrossRef\]](#)
116. Donner, M.; Gohier, R.; de Vries, H. A new circular business model typology for creating value from agro-waste. *Sci. Total Environ.* **2020**, *716*, 137065. [\[CrossRef\]](#) [\[PubMed\]](#)
117. Rondón-Quintana, H.A.; Reyes-Lizcano, F.A.; Chaves-Pabón, S.B.; Bastidas-Martínez, J.G.; Zafra-Mejía, C.A. Use of biochar in asphalts. *Sustainability* **2022**, *14*, 4745. [\[CrossRef\]](#)
118. Kumar, A.; Choudhary, R.; Narzari, R.; Kataki, R.; Shukla, S.K. Evaluation of bio-asphalt binders modified with biochar: A pyrolysis by-product of Mesua ferrea seed cover waste. *Cogent Eng.* **2018**, *5*, 1548534. [\[CrossRef\]](#)
119. Çeloğlu, M.E.; Mehmet, Y.; Kök, B.V.; Yalçın, E. Effects of various biochars on the high temperature performance of bituminous binder. In Proceedings of the 6th Euraphalt & Eurobitume Congress, Prague, Czech Republic, 1–3 June 2016; pp. 1–3.
120. de Melo Barbosa, A.; Machado dos Santos, G.; Medeiros de Melo, G.M.; Litaiff, H.A.; Martorano, L.G.; Giacon, V.M. Evaluation of the use of açai seed residue as reinforcement in polymeric composite. *Polym. Polym. Compos.* **2022**, *30*, 09673911221108307. [\[CrossRef\]](#)
121. Verdi, A.G.; de Souza, A.G.; Rocha, D.B.; de Oliveira, S.A.; Alves, R.M.V.; dos Santos Rosa, D. Biodegradable films functionalized with Moringa oleifera applied in food packaging. *Iran. Polym. J.* **2021**, *30*, 235–246. [\[CrossRef\]](#)
122. Ruggiero, A.; Valášek, P.; Müller, M. Exploitation of waste date seeds of Phoenix dactylifera in form of polymeric particle biocomposite: Investigation on adhesion, cohesion and wear. *Compos. Part B Eng.* **2016**, *104*, 9–16. [\[CrossRef\]](#)
123. Kadhim, N.N.; Hamad, Q.A.; Oleiwi, J.K. Tensile and morphological properties of PMMA composite reinforced by Pistachio Shell powder used in denture applications. In *AIP Conference Proceedings*; AIP Publishing: College Park, MD, USA, 2020; Volume 2213.
124. Liminana, P.; Garcia-Sanoguera, D.; Quiles-Carrillo, L.; Balart, R.; Montanes, N. Development and characterization of environmentally friendly composites from poly (butylene succinate) (PBS) and almond shell flour with different compatibilizers. *Compos. Part B Eng.* **2018**, *144*, 153–162. [\[CrossRef\]](#)
125. Agunsoye, J.O.; Bello, S.A.; Adetola, L.O. Experimental investigation and theoretical prediction of tensile properties of *Delonix regia* seed particle reinforced polymeric composites. *J. King Saud. Univ. Eng. Sci.* **2019**, *31*, 70–77. [\[CrossRef\]](#)
126. Nwogu, C.N.; Nwaiwu, U.; Udo, V.U.; Nwosu, O.J.; Hart, C.E. Effect of date seed granules on the mechanical properties of Glass fibre reinforced epoxy composite. *Clean. Mater.* **2022**, *6*, 100160. [\[CrossRef\]](#)
127. Rajkumar, K.; Vinoth, N.; Kumar, R.S.; Sathish, T.; Subbiah, R.; Ravichandran, M.; Mohanavel, V. Mechanical and water absorption behaviour of palm seed particles based hybrid bio-composites. In *Journal of Physics: Conference Series; Proceedings of International Conference on Recent Advancements in Biomedical Engineering 2021 (ICRABE 2021) 17–19 March 2021, Chennai, India*; IOP Publishing: Bristol, UK, 2021; Volume 2027, p. 012006.
128. Hyseni, A.; De Paola, S.; Minak, G.; Fragassa, C. Mechanical Characterization of EcoComposites. In Proceedings of the 30th Danubia Adria Symposium on Advanced Mechanics, Primosten, Croatia, 25–28 September 2013; Croatian Society of Mechanics, Ed.; pp. 175–176.
129. Koutsomitopoulou, A.F.; Bénézet, J.C.; Bergeret, A.; Papanicolaou, G.C. Preparation and characterization of olive pit powder as a filler to PLA-matrix bio-composites. *Powd. Technol.* **2014**, *255*, 10–16. [\[CrossRef\]](#)
130. Mills, J.S.; Werner, A.E.A. The chemistry of dammar resin. *J. Chem. Soc. Resumed* **1955**, 3132–3140. [\[CrossRef\]](#)
131. Franz, M.H.; Neda, I.; Maftai, C.V.; Ciuca, I.; Bolcu, D.; Stănescu, M.M. Studies of chemical and mechanical properties of hybrid composites based on natural resin Dammar formulated by epoxy resin. *Polym. Bull.* **2021**, *78*, 2427–2438. [\[CrossRef\]](#)
132. Stănescu, M.M.; Bolcu, A. A study of the mechanical properties in composite materials with a dammar based hybrid matrix and reinforcement from crushed shells of sunflower seeds. *Polymers* **2022**, *14*, 392. [\[CrossRef\]](#) [\[PubMed\]](#)
133. Chen, J.; Huang, Y.; Deng, L.; Jiang, H.; Yang, Z.; Yang, R.; Wu, D. Preparation and research of PCL/cellulose composites: Cellulose derived from agricultural wastes. *Int. J. Biol. Macromol.* **2023**, *235*, 123785. [\[CrossRef\]](#)
134. Puglia, D.; Dominici, F.; Badalotti, M.; Santulli, C.; Kenny, J.M. Tensile, thermal and morphological characterization of Cocoa Bean Shells (CBS)/Polycaprolactone based composites. *J. Renew. Mater.* **2016**, *4*, 199–205. [\[CrossRef\]](#)
135. De Monte, C.; Arrighetti, L.; Ricci, L.; Civello, A.; Bronco, S. Agro-Waste Bean Fibers as Reinforce Materials for Polycaprolactone Composites. *Compounds* **2023**, *3*, 504–520. [\[CrossRef\]](#)

136. Stalin, B.; Nagaprasad, N.; Vignesh, V.; Ravichandran, M.; Rajini, N.; Ismail, S.O.; Mohammad, F. Evaluation of mechanical, thermal and water absorption behaviors of *Polyalthia longifolia* seed reinforced vinyl ester composites. *Carbohydr. Polym.* **2020**, *248*, 116748. [\[CrossRef\]](#)
137. Kolář, V.; Tichý, M.; Müller, M. Mechanical properties of polymeric composite based on pine seeds production residues. *Manuf. Technol.* **2019**, *19*, 426–430. [\[CrossRef\]](#)
138. Felix Sahayaraj, A.; Muthukrishnan, M.; Ramesh, M. Influence of Tamarindus indica seed nano-powder on properties of *Luffa cylindrica* (L.) fruit waste fiber reinforced polymer composites. *Polym. Compos.* **2022**, *43*, 6442–6452. [\[CrossRef\]](#)
139. Saw, S.K.; Purwar, R.; Nandy, S.; Ghose, J.; Sarkhel, G. Fabrication, characterization, and evaluation of luffa cylindrica fiber reinforced epoxy composites. *BioResources* **2013**, *8*, 4805–4826. [\[CrossRef\]](#)
140. Papanicolaou, G.C.; Psarra, E.; Anastasiou, D. Manufacturing and mechanical response optimization of epoxy resin/*Luffa Cylindrica* composite. *J. Appl. Polym. Sci.* **2015**, *132*, 41992. [\[CrossRef\]](#)
141. Tesfaye, T.; Ayele, M.; Ferede, E.; Gibril, M.; Kong, F.; Sithole, B. A techno-economic feasibility of a process for extraction of starch from waste avocado seeds. *Clean. Technol. Environ. Policy* **2021**, *23*, 581–595. [\[CrossRef\]](#)
142. Neelam, K.; Vijay, S.; Lalit, S. Various techniques for the modification of starch and the applications of its derivatives. *Int. Res. J. Pharm.* **2012**, *3*, 25–31.
143. Admase, A.T.; Aynalem, M.D.; Ashagrie, T.A.; Melaku, Y.M.; Agdew, S.A. Utilization of Starch from Waste Avocado Seed for the Manufacture of Sustainable Bio-Based Adhesive Reinforced with Clay Particles. In *Advancement of Science and Technology: Materials and Energy*; Springer Nature: Cham, Switzerland, 2023; pp. 367–379.
144. Bangar, S.P.; Kumar, M.; Whiteside, W.S.; Tomar, M.; Kennedy, J.F. Litchi (*Litchi chinensis*) seed starch: Structure, properties, and applications—A review. *Carbohydr. Polym. Technol. Appl.* **2021**, *2*, 100080. [\[CrossRef\]](#)
145. Tosif, M.M.; Najda, A.; Bains, A.; Zawislak, G.; Maj, G.; Chawla, P. Starch–mucilage composite films: An inclusive on physico-chemical and biological perspective. *Polymers* **2021**, *13*, 2588. [\[CrossRef\]](#) [\[PubMed\]](#)
146. Krystijan, M.; Khachatryan, G.; Ciesielski, W.; Buksa, K.; Sikora, M. Preparation and characteristics of mechanical and functional properties of starch/*Plantago psyllium* seeds mucilage films. *Starch-Stärke* **2017**, *69*, 1700014. [\[CrossRef\]](#)
147. Mujtaba, M.; Koc, B.; Salaberria, A.M.; Ilk, S.; Cansaran-Duman, D.; Akyuz, L.; Cakmak, Y.S.; Kaya, M.; Khawar, K.M.; Boufi, S.; et al. Production of novel chia-mucilage nanocomposite films with starch nanocrystals; An inclusive biological and physicochemical perspective. *Int. J. Biol. Macromol.* **2019**, *133*, 663–673. [\[CrossRef\]](#)
148. Nayak, A.K.; Alkahtani, S.; Hasnain, M.S. Jackfruit seed starch-based composite beads for controlled drug release. In *Polymeric and Natural Composites: Materials, Manufacturing and Biomedical Applications*; Hasnain, M.S., Nayak, A.K., Alkahtani, S., Eds.; Springer: Cham, Switzerland, 2022; pp. 213–240.
149. Shahbazadeh, S.; Naji-Tabasi, S.; Shahidi-Noghabi, M. Development of soy protein/sodium alginate nanogel-based cress seed gum hydrogel for oral delivery of curcumin. *Chem. Biol. Technol. Agric.* **2022**, *9*, 41. [\[CrossRef\]](#)
150. Castaño, J.; Rodríguez-Llamazares, S.; Carrasco, C.; Bouza, R. Physical, chemical and mechanical properties of pehuen cellulosic husk and its pehuen-starch based composites. *Carbohydr. Polym.* **2012**, *90*, 1550–1556. [\[CrossRef\]](#)
151. Kanmani, P.; Rhim, J.W. Development and characterization of carrageenan/grapefruit seed extract composite films for active packaging. *Int. J. Biol. Macromol.* **2014**, *68*, 258–266. [\[CrossRef\]](#)
152. Alami, A.H. Mechanical and thermal properties of solid waste-based clay composites utilized as insulating materials. *Int. J. Therm. Environ. Eng.* **2013**, *6*, 89–94.
153. Akhund, M.A.; Khoso, A.R.; Pathan, A.A.; Memon, U.; Siddiqui, F.H. Influence of biomass aggregate on strength of foam concrete. *Int. J. Civ. Eng. Technol.* **2017**, *8*, 1645–1653.
154. Agrela, F.; Beltran, M.G.; Cabrera, M.; López, M.; Rosales, J.; Ayuso, J. Properties of recycled concrete manufacturing with all-in recycled aggregates and processed biomass bottom ash. *Waste Biomass Valorization* **2018**, *9*, 1247–1259. [\[CrossRef\]](#)
155. Rosales, M.; Rosales, J.; Agrela, F.; de Rojas, M.S.; Cabrera, M. Design of a new eco-hybrid cement for concrete pavement, made with processed mixed recycled aggregates and olive biomass bottom ash as supplementary cement materials. *Constr. Build. Mater.* **2022**, *358*, 129417. [\[CrossRef\]](#)
156. Moujoud, Z.; Harrati, A.; Manni, A.; Naim, A.; El Bouari, A.; Tanane, O. Study of fired clay bricks with coconut shell waste as a renewable pore-forming agent: Technological, mechanical, and thermal properties. *J. Build. Eng.* **2023**, *68*, 106107. [\[CrossRef\]](#)
157. Bheel, N.; Mangi, S.A.; Lal, S. Coconut shell ash as cementitious material in concrete: A review. *J. Kejuruter.* **2021**, *33*, 27–38. [\[CrossRef\]](#) [\[PubMed\]](#)
158. Yerramala, A.; Ramachandrudu, C. Properties of concrete with coconut shells as aggregate replacement. *Int. J. Eng. Invent.* **2012**, *1*, 21–31.
159. Freire, A.L.F.; de Araújo Júnior, C.P.; de Freitas Rosa, M.; de Almeida Neto, J.A.; de Figueirêdo, M.C.B. Environmental assessment of bioproducts in development stage: The case of fiberboards made from coconut residues. *J. Clean. Prod.* **2017**, *153*, 230–241. [\[CrossRef\]](#)
160. Boros, A.; Tózsér, D. The Emerging Role of Plant-Based Building Materials in the Construction Industry—A Bibliometric Analysis. *Resources* **2023**, *12*, 124. [\[CrossRef\]](#)
161. Ni, S.; Liu, H.; Li, Q.; Quan, H.; Gheibi, M.; Fathollahi-Fard, A.M.; Tian, G. Assessment of the engineering properties, carbon dioxide emission and economic of biomass recycled aggregate concrete: A novel approach for building green concretes. *J. Clean. Prod.* **2022**, *365*, 132780. [\[CrossRef\]](#)

162. Abu-Jdayil, B.; Mourad, A.H.I.; Hussain, A.; Al Abdallah, H. Thermal insulation and mechanical characteristics of polyester filled with date seed wastes. *Constr. Build. Mater.* **2022**, *315*, 125805. [\[CrossRef\]](#)
163. Barkhad, M.S.; Abu-Jdayil, B.; Iqbal, M.Z.; Mourad, A.H.I. Thermal insulation using biodegradable poly (lactic acid)/date pit composites. *Constr. Build. Mater.* **2020**, *261*, 120533. [\[CrossRef\]](#)
164. Alsalam, Z.H.A.; Harith, I.K.; Dhahir, M.K. Utilization of dates palm kernel in high performance concrete. *J. Build. Eng.* **2018**, *20*, 166–172. [\[CrossRef\]](#)
165. Muthusamy, K.; Nordin, N.; Vesuvapateran, G.; Ali, M.; Harun, H.; Ullap, H. Research Article Exploratory Study of Rubber Seed Shell as Partial Coarse Aggregate Replacement in Concrete. *Res. J. Appl. Sci. Eng. Technol.* **2014**, *7*, 1199–1202. [\[CrossRef\]](#)
166. Beskopylny, A.N.; Shcherban', E.M.; Stel'makh, S.A.; Meskhi, B.; Shilov, A.A.; Varavka, V.; Evtushenko, A.; Özkılıç, Y.O.; Aksoylu, C.; Karalar, M. Composition component influence on concrete properties with the additive of rubber tree seed shells. *Appl. Sci.* **2022**, *12*, 11744. [\[CrossRef\]](#)
167. Sisman, C.B.; Gezer, E. Sunflower seed waste as lightweight aggregate in concrete production. *Int. J. Environ. Waste Manag.* **2013**, *12*, 203–212. [\[CrossRef\]](#)
168. Das Lala, S.; Deb, P.; Barua, E.; Deoghare, A.B.; Chatterjee, S. A comparative study on mechanical, physico-chemical, and thermal properties of rubber and walnut seed shell reinforced epoxy composites and prominent timber species. *Proc. Inst. Mech. Eng. Part C J. Mech. Eng. Sci.* **2023**, *237*, 1165–1177. [\[CrossRef\]](#)
169. Devasahayam, S.; Yarlagadda, P. Mechanics of polypropylene-seed-coat-fibres composites and polypropylene-wood fibres composites—A comparative study. *Procedia Eng.* **2014**, *97*, 1915–1928. [\[CrossRef\]](#)
170. Girimurugan, R.; Babu, B.; Saravanan, R.; Vigneshwaran, M.; Mehanathan, S. Effect of kapok seed powder on mechanical and water intake properties of untreated kenaf fiber composites. *Mater. Today Proc.* **2023**. [\[CrossRef\]](#)
171. Babu, B.; Bensam Raj, J.; Jeya Raj, R.; Roshan Xavier, X. Investigation on the mechanical properties of natural composites made with Indian almond fiber and neem seed particulates. *Proc. Inst. Mech. Eng. C J. Mech. Eng. Sci.* **2023**, *237*, 09544062231167018. [\[CrossRef\]](#)
172. Nova, M.; Arévalo, Y.; Murillo, E.A. Functionalization in solution of polypropylene with a maleinized hyperbranched polyol polyester: Structural, thermal, rheological, and mechanical properties. *J. Appl. Polym. Sci.* **2019**, *136*, 46932. [\[CrossRef\]](#)
173. Hamma, A.; Dairi, B.; Bouhelal, S. Valorization of date seeds wastes as reinforcement for starch-grafted-polypropylene composites. *J. Fundam. Appl. Sci.* **2022**, *14*, 135–160. [\[CrossRef\]](#)
174. Santulli, C.; Mastrodonato, L. LCA of biomass-based food packaging materials. In *Biopolymers and Biocomposites from Agro-Waste for Packaging Applications*; Saba, N., Jawaideh, M., Thariq, M., Eds.; Woodhead Publishing: Sawston, UK, 2021; pp. 219–234.
175. Zalazar-Garcia, D.; Fernandez, A.; Cavaliere, L.; Deng, Y.; Soria, J.; Rodriguez, R.; Mazza, G. Slow pyrolysis of pistachio-waste pellets: Combined phenomenological modeling with environmental, exergetic, and energetic analysis (3-E). *Biomass Convers. Biorefin* **2022**. [\[CrossRef\]](#)
176. Kumar, S.; Singh, J.; Nanoti, S.M.; Garg, M.O. A comprehensive life cycle assessment (LCA) of Jatropha biodiesel production in India. *Bioresour. Technol.* **2012**, *110*, 723–729. [\[CrossRef\]](#) [\[PubMed\]](#)
177. Khanam, T.; Khalid, F.; Manzoor, W.; Rashedi, A.; Hadi, R.; Ullah, F.; Rehman, F.; Akhtar, A.; Babu, N.K.; Hussain, M. Environmental sustainability assessment of biodiesel production from *Jatropha curcas* L. seeds oil in Pakistan. *PLoS ONE* **2021**, *16*, e0258409. [\[CrossRef\]](#) [\[PubMed\]](#)
178. Campiglia, E.; Gobbi, L.; Marucci, A.; Rapa, M.; Ruggieri, R.; Vinci, G. Hemp seed production: Environmental impacts of Cannabis sativa L. Agronomic practices by life cycle assessment (LCA) and carbon footprint methodologies. *Sustainability* **2020**, *12*, 6570. [\[CrossRef\]](#)
179. Manthey, N.W.; Cardona, F.; Francucci, G.; Aravinthan, T. Thermo-mechanical properties of acrylated epoxidized hemp oil based biocomposites. *J. Compos. Mater.* **2014**, *48*, 1611–1622. [\[CrossRef\]](#)
180. Akhtar, M.T.; Ahmad, M.; Ramadan, M.F.; Makhkamov, T.; Yuldashev, A.; Mamarkhimov, O.; Munir, M.; Asma, M.; Zafar, M.; Majeed, S. Sustainable Production of Biodiesel from Novel Non-Edible Oil Seeds (*Descurainia sophia* L.) via Green Nano CeO₂ Catalyst. *Energies* **2023**, *16*, 1534. [\[CrossRef\]](#)
181. Massironi, A.; Biella, S.; de Moura Pereira, P.F.; Scibona, F.; Feni, L.; Sindaco, M.; Emide, D.; Jiménez-Quero, A.; Bianchi, C.L.M.; Marzorati, S.; et al. Valorization of pumpkin seed hulls, cucurbitin extraction strategies and their comparative life cycle assessment. *J. Clean. Prod.* **2023**, *427*, 139267. [\[CrossRef\]](#)
182. Muhamad, H.; Ai, T.Y.; Khairuddin, N.S.K.; Amiruddin, M.D.; May, C.Y. Life cycle assessment for the production of oil palm seeds. *Trop. Life Sci. Res.* **2014**, *25*, 41.
183. Prasad, L.; Singh, G.; Yadav, A.; Kumar, V.; Kumar, A. Properties of functionally gradient composites reinforced with waste natural fillers. *Acta Period. Technol.* **2019**, *50*, 250–259. [\[CrossRef\]](#)
184. Kazemi, H.; Parot, M.; Stevanovic, T.; Mighri, F.; Rodrigue, D. Cellulose and lignin as carbon black replacement in natural rubber. *J. Appl. Polym. Sci.* **2022**, *139*, e52462. [\[CrossRef\]](#)
185. Ruggiero, A.; Valášek, P.; Müller, M.; D'Amato, R. Tribological investigation of epoxy/seed particle composite obtained from residues of processing *Jatropha Curcas* L. fruits. *Compos. Part B Eng.* **2019**, *167*, 654–667. [\[CrossRef\]](#)
186. Siddiqui, S.I.; Zohra, F.; Chaudhry, S.A. Nigella sativa seed based nanohybrid composite-Fe₂O₃-SnO₂/BC: A novel material for enhanced adsorptive removal of methylene blue from water. *Environ. Res.* **2019**, *178*, 108667. [\[CrossRef\]](#)

187. Rathi, G.; Siddiqui, S.I.; Pham, Q. Nigella sativa seeds based antibacterial composites: A sustainable technology for water cleansing-A review. *Sustain. Chem. Pharm.* **2020**, *18*, 100332. [[CrossRef](#)]
188. Serrano, A.; Ángel Siles López, J.; Chica, A.F.; Martin, M.; Karouach, F.; Mesfioui, A.; El Bari, H. Mesophilic anaerobic co-digestion of sewage sludge and orange peel waste. *Environ. Technol.* **2014**, *35*, 898–906. [[CrossRef](#)] [[PubMed](#)]
189. Foroutan, R.; Peighambaroust, S.J.; Ghojavand, S.; Foroughi, M.; Ahmadi, A.; Bahador, F.; Ramavandi, B. Development of a magnetic orange seed/Fe₃O₄ composite for the removal of methylene blue and crystal violet from aqueous media. *Biomass Convers. Biorefinery* **2023**, 1–16. [[CrossRef](#)]
190. Mphuthi, B.R.; Thabede, P.M.; Monapathi, M.E.; Shooto, N.D. Hemp seed nanoparticle composites for removing lead, methylene blue, and ibuprofen from an aqueous solution and their antimicrobial towards *Escherichia coli* and *Staphylococcus aureus*. *Case Stud. Chem. Env. Eng.* **2023**, *8*, 100436. [[CrossRef](#)]
191. Revathi, T.; Thambidurai, S. Immobilization of ZnO on Chitosan-Neem seed composite for enhanced thermal and antibacterial activity. *Adv. Powd Technol.* **2018**, *29*, 1445–1454. [[CrossRef](#)]
192. Salih, S.I.; Oleiwi, J.K.; Mohamed, A.S. Investigation of mechanical properties of PMMA composite reinforced with different types of natural powders. *ARN J. Eng. Appl. Sci.* **2018**, *13*, 8889–8900.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.