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An extrudable composition comprised of waste polyolefins and an alkali metal bicarbonate salt/solid, saturated fatty acid foaming agent system, and a method for extruding such extrudable composition wherein the fatty acid/bicaronate foaming agent system foams the waste polyolefins during the extrusion to produce end products which have qualities closely simulating natural lumber suitable for use as construction materials.

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EXTRUSION METHOD AND APPARATUS FOR RECYCLING WASTE PLASTICS AND CONSTRUCTION MATERIALS THEREFROM

BACKGROUND OF THE INVENTION

The invention is directed to an extrudable compound, an extrusion method using primarily waste polyolefin starting materials, and articles manufactured through such processes which simulate conventional outdoor construction lumber.

There are many advantages to recycling waste plastics both economical and ecological. Discarded waste plastics are available at comparatively negligible costs since they are essentially garbage. Furthermore, the present invention provides an economic incentive to remove waste plastics, which ordinarily are not completely biodegradable, from the environment.

Waste polyolefins and other waste plastics are different from plastics fresh off a plastic manufacturer's production line because these materials have served their intended use, been discarded and exposed, often for lengthy periods, to the environment. This relatively lengthy exposure to the elements produces changes in the physical and chemical properties of the plastics. Generally, waste plastics have lower tensile strength and relatively poorer flex and thermal properties when compared to new plastics fresh off the production line.

Since waste polyolefins are not completely biodegradable, they have life cycles which are much longer than conventional wooden building materials. In addition, construction materials made from waste polyolefins have chemical, biological, mechanical, electrical and flame resistance properties superior to counterpart natural lumber products.

Surprisingly, only limited attempts have been made to develop lumber-substitute construction products from waste polyolefins. For example, U.S. Patent No. 4,003,866 teaches construction material made from waste thermoplastic resins and other non-plastic fillers. The non-plastic fillers are coated or encapsulated with a recycled polyethylene or polypropylene wax. Because of the complexity of the process disclosed and the limited improvement provided by the wax encapsulated materials over natural materials, the products made from this disclosure have very narrow practical application.

Maczko, J., A System to Mold Mixed, Contaminated Plastics into Wood, Metal and Concrete Replacements, RECYCLINGPLAS II, Conference of Plastics Institute of America, June 1819, 1987, Washington, D.C., describes the ET-1 process for producing substitute construction materials from waste plastics. The described method is claimed to be able to transform mass waste plastics directly into a large range of molded end products without presorting of any kind, and without the need for inserting any additives to the intermediate resin.

The ET-1 process melts resins in a short-screw extruder, then forces the heated extrudate into a series of linear molds which are then mounted onto a turret. The heated molds cool as the turret rotates them through a water filled tank. The end products are air-ejected from open ends of the molds.

The ET-1 end product is essentially a solid with randomly spaced voids. It has a typical specific gravity slightly higher than 1.0 gm/cc, making it heavier than most natural timber products (ordinarily, wood floats on water because it has a density less than that of water). The length of the end products are limited by the size of the mold into which the extruder can inject and fill with resin. Practically, as construction material, these end products are generally difficult to cut, saw, nail or drill holes into.

Accordingly, there is a need for a recycled waste plastic material which has qualities closely resembling natural lumber such as consistency, texture and density which will be readily accepted by the construction industry as a replacement for wood. Such, materials can be used by architects, construction engineers and manual construction laborers by applying their currently known skills to the use of such recycled waste plastic products.

Known extrusion methods have not been able to satisfactorily convert waste plastics into products that have uniform dimension due to variations in the feed composition, and the end products produced, undesirably and unpredictably, vary in size, configuration and thickness. The need therefore exists for an extrusion process which produces end products derived from waste plastics with substantially uniform dimensions conforming to conventional construction standards of any desired length.

SUMMARY OF THE INVENTION

To overcome the problems and deficiencies of the currently available art, the present invention provides an improved, extrudable composition; an extrusion method for continuously producing improved composites from waste polyolefins; and the improved, composite end product which closely resembles construction lumber.

The extrudable composition used as the starting material contains at least 50% waste polyolefin; from 0.1% to 1.5% of a Group IA alkali metal bicarbonate; and from 0.6 to 2.0 molar equivalents of the bicarbonate salt (1:1 to 2:1 molar ratio with respect to the alkali metal bicarbonate), of a saturated fatty acid, which is solid at room temperature (20'C, 1 atm). The preferred alkali metal salts are sodium or potassium bicarbonate. Suitable saturated fatty acids include those with carbon chains of from 14 to 22 carbons such as myristic acid, palmitic acid, stearic acid, arachidic acid, and mixtures, such as tallow fatty acids. The preferred foaming agent system is a sodium bicarbonate/solid stearic acid combination.

The foaming agent components react in situ in the waste polyolefin to form products which serve several functions. Using, the preferred system, for example, in addition to the formation of C02 for foaming, sodium stearate is formed by the reaction of the sodium bicarbonate wi th the stearic acid. Sodium stearate, along with unreacted stearic acid, helps disperse the filler materials during extrusion. The stearate also lubricates the melt in the extruder as the semisolid mass passes through the sizing sleeve, reducing "seizing" and sticking. The sodium stearate present in the final product also acts as a hydrogen chloride scavenger, and as an anionic compound which helps "bleed off" static charges which may otherwise build up during actual use of the end product.

The extruded products have a specific gravity of from 0.4 gm/cc to 0.9 gm/cc, in contrast to conventional recycled waste plastic compositions which generally have specific gravities in excess of 1.0 gm/cc. The foaming serves to reduce the density in the final product thereby saving the amount of raw materials required for a given volume and increases the strength to weight ratios of the end products.

In the extrudable composition, the preferred resin is that obtained by grinding postconsumer mixed plastics containing mainly polyolefins. The term "polyolefins" as used herein refers to HDPE, LDPE, LLDPE, UHMWPE, homopolymers of polypropylene, copolymers of ethylene and propylene, and combinations thereof.

"Waste polyolefins" as the term is used herein, contains at least 80% by weight polyolefins as defined above and, additionally, from about 0.5% to about 20% by weight of one or more other polymeric materials such as rigid or flexible PVC; polystyrene; chlorosulfonated polyethylenes; unmodified, compounded, reinforced, alloys or blends of engineering plastics such as polyamides, polycarbonates, thermoplastic polyesters (PET or PBT), ABS, polyphenylene oxide and polyacetals; and combinations thereof.

As is evident from the preceding, the waste polyolefins used as the starting materials for the present invention are a heterogeneous mixture of a wide range of plastics. They are obtained from industrial, commercial and residential garbage by initially removing the bulk of nonplastic contaminants such as dirt, spoiled food, paper, cloth and metals.

The compositions of the present invention may also include fibrous reinforcing agents for providing strength and improved impact properties to the molded end products, and filler materials for providing stiffness, additional strength, and enhanced mechanical and heat resistance. The reinforcing agent can be present in amounts from 0 to 50% of total weight of the composition, preferably at least 20% of total weight; and the filler materials from 0 to 20% of total weight, preferably at least 5% of total weight of the composition. Both the reinforcer and the filler content are adjusted to the type and quality of end product desired.

The preferred reinforcing agent is chopped strands of glass fiber. Appropriate coupling agents, such as silanes or organs-titanates, can also be used to enhance reinforcement.

Filler materials which can be used include calcium carbonate, asbestos, mica, wollastonite, talc, diatomaceous earth, kaolin clays, alumina trihydrates, calcium metasilicate, metal flakes, ceramics, carbon filaments and the like. A single filler or a combination of fillers can be added, and the filler can also be derived from recyclable waste.

The extrudable composition may also be a foam composition having a specific gravity of 0.4 to 0.9 gm/cc formed by a continuous extrusion process in the presence of a saturated fatty acid and an alkali metal bicarbonate in a molar ratio of from 1:1 to 2:1 and suitable for use as a substitute for construction lumber. At least 50%, based on total weight of said composition, of a used polyolefinic material derived from residential, commercial, or industrial waste is used. An anionic salt of an alkali metal carboxylate of a saturated fatty acid and about 2% to 50% of a reinforcing agent are also incorporated.

The method of making a composite foam extruded product which simulates lumber includes the steps of continuously supplying to an extruder used polyolefinic material derived from residential, commercial, or industrial waste; blending with the polyolefinic material an alkali metal bicarbonate and a saturated fatty acid which is a solid at room temperature, said bicarbonate being at a concentration of about 0.1% to 1.5% of total weight of the blend and the fatty acid being in a molar ratio of from about 1:1 to 2:1 with respect to the bicarbonate and about 2% to 50% of a reinforcing agent; extruding a melt of the blend through a profile die; forming a foaming agent and a lubricant for the blend by the insitu reaction of the bicarbonate and the fatty acid; feeding the lubricated blend from the die into a sizing zone wherein the blend is foamed to substantially its final cross-section; cooling the thus-foamed material in the sizing zone so as to rigidify the foamed material; and forcing and pulling the rigidified material through and from the sizing zone.

DETAILED DESCRIPTION OF THE INVENTION

The extrusion apparatus used in the invention includes a feeding section, a mixing section, and a shaping section.

When waste polyolefins are finely sorted (i.e. a relatively more detailed presorting for impurities such as paper, dirt, spoiled food, metals and nonwaste polyolefins is performed), the feeding section, which includes a shredder, can be eliminated, and the presorted waste polyolefins can be fed directly into the mixing section.

The mixing section includes a hopper, a reinforcing agent storage container, a foaming agent storage container, and an extruder. Channels provide for communication between the input end of the hopper and storage containers. The discharge end of the hopper communicates with an opening in the extruder.

The reinforcing agent is introduced from a storage container into the waste polyolefins. Filler materials can also be added at this point.

The extruder has a conventional screw which rotates to force the waste polyolefin stream out of the discharge end of extruder and into the die of the shaping section. The screw also functions to further mix the foaming agent and reinforcing agent with the waste polyolefin stream. The extruder has a conventional heating means to convert the waste polyolefin stream into a molten state.

When relatively finer presorted waste polyolefins are involved, the polyolefins are introduced directly into the hopper. If the feed is composed of many different types of waste polyolefins (as defined above), they can be dry blended before being introduced into the extruder. The waste polyolefin stream can alternatively be preblended with the reinforcing agent and the foaming agent system prior to introduction into the hopper.

Turning now to the shaping section which is disposed downstream of the mixing section, it includes a die, a die extension communicating with the die, a sizing sleeve, and a puller or take away means. The extrudate emerging from the extruder is forced through the die and the die extension by the screw of the extruder. Most of the foaming occurs in the die extension. The sizing sleeve, disposed downstream of the die extension, is dimensioned so that its inside diameter corresponds to the maximum desired outside diameter of the end product.

The puller operates to pull the extrudate through the sizing sleeve. The puller can be of any conventional type such as a plurality of rollers which grip the extrudate therebetween. The sizing sleeve is immersed in a water trough, as is known in the art, to cool the extrudate and to rigidify it as it exits from the sizing sleeve.

As stated above, use of the foaming agent in the present method enables the production of a recycled plastic wh ich has wood like densities evenly and continuously distributed throughout the end product, and which can be extruded to any desirable dimension. These composites can be nailed, screwed, sawed and bolted with conventional woodworking tools and skills, and unlike wood, these products will not rot and degrade when exposed to the environment and the strength of the product will remain constant whether wet or dry.

The end product compositions of the present invention do not require addition of conventional stabilizers to protect against thermo-oxidative degradation, because the polymer resin matrix derived from waste plastics generally contains stabilizers. Random samplings of collected waste plastics contain from 0.05 to 0.5% stabilizer based on the total polymer resin matrix. However, the invention contemplates addition of useful stabilizers such as those well known in the art if necessary.

To the compositions of this invention there may additionally be added ultraviolet absorbers and antifungal agents, depending on the ultimate intended use of the extruded product.

In addition to extrusion, the compositions of this invention may be injection molded to produce commercially usable products. To such ends, other additives can be used, including impact modifiers, viscosity stabilizers, processing aids, and coloring agents.

The following examples demonstrate the actual production of the compositions of the present invention.

EXAMPLE I

Initially, a comparative study was performed using various forms of organic acid/sodium bicarbonate foaming agent systems. As this example demonstrates, the stearic acid system showed the lowest density end product.

To one pound of high density polyethylene was added the following organic acids with a stoichiometric equivalent, (4.52 gm) of sodium bicarbonate. The two ingredients were dry blended with the polyethylene. The blends were then extruded by the use of a 1 inch extruder with the following temperature profile: the melting zone, 200'C; the pumping/metering zone 180-210'C; and die temperature, 200'C.

Sample strands of final product were collected and their specific gravities measured. The results are summarized in the following table:

TABLE 1

Sample (gm/cc)	Organic acid (gm)	Specific gravity of foam
control	---	0.95
stearic acid	14.7	0.47
isophthalic acid	4.5	0.62
benzoic acid	6.1	0.60
citric acid	4.5	0.80

EXAMPLE 2

A masterbatch of foaming agent was prepared by mixing the following ingredients in the following ratios:

	Parts
Mica (carrier/filler material)	50.0
NaHC03	3.0
Stearic Acid	9.0

In a twin screw extruder (Berstorff™ ZE 40-A) was fed a blend of 25% glass fibers and 72k, high density polyethylene (0.7 melt index, 0.96 gm/cc). As a side feed, 4% of masterbatch was added (to give 0.2 and 0.6 weight [t] foaming agent, NaHC03-stearic acid). The melt was forced through a die and a sizing sleeve and into a water trough to give a 2 x 4 inch extruded structure resembling wood. The expected specific gravity for high density polyethylene with 25% glass fiber was 1.2 gm/cc. Surprisingly, the density of the extrudate was found to be 0.69 gm/cc. Smooth extrusion with good filler dispersion was observed. Evenly distributed, uniform foam structure was observed during extruding.

EXAMPLE 3

Commingled waste polyolefin plastic containers randomly obtained from household, curb-side garbage, after substantial separation of PET carbonated beverage containers, were put through a grinder and reduced to flake.

A masterbatch foam system of the following composition was prepared by mixing the following ingredients in the following ratios:

50.0 parts ground mollusk shells (97.5% CaC03)
9.0 parts stearic acid
3.0 parts sodium bicarbonate

The following components were fed to a twin-screw 60 mm extruder:

	PARTS
Ground waste polyolefin flakes	70.0
Glass fibers	20.0
Masterbatch foam system	10.0

The three ingredients were metered separately, the ground polyolefin flakes at the throat of the extruder, and the glass fiber and masterbatch through a side-feeder at a point where the resin was molten. The total feed was 300 lbs/hr. A smooth extrusion with no sticking in the sizing sleeve and a good dispersion of the glass fibers and ground mollusk shells materials was observed. The density of the continuously extruded end product over an 8 hour period was between 0.73 to 0.88 gm/cc.

EXAMPLE 4

A series of compositions were made using various fillers and resin blends using the same rates as in Example 3. The resulting densities of these compositions are shown in Tables 2 and 3. The numerals which precede percentage symbols denote the percentage concentration of that particular ingredient relative to the total weight of the end products.

TABLE 2

COMPOSITION NO.:	1	2	3	4	5
INGREDIENT					
WASHED WASTE POLYOLEFIN				71.9%	
UNWASHED WASTE POLYOLEFIN	71.9%	71.9%	56.7%		61.9%
POLYSTYRENE			15.2%*		10.0%**
WASTE GLASS FIBER		20.0%	20.0%	20.0%	20.0%
PRIME GLASS FIBER	20.0%				
GROUND OYSTER SHELLS	6.5%	6.5%	6.5%	6.5%	6.5%
STEARIC ACID	1.2%	1.2%	1.2%	1.2%	1.2%
SODIUM BICARBONATE	0.4%	0.4%	0.4%	0.4%	0.4%
DENSITY gm/cc.	0.78	0.77	0.79	0.80	0.78

* Crystalline polystyrene

** Expandable polystyrene

TABLE 3

COMPOSITION NO.:	6	7	8	9	10
INGREDIENT					
GROUND WASTE POLYOLEFIN	37.3%	34.8%	71.9%	71.9%	71.9%
GROUND WASTE POLYPROPYLENE	34.6%	34.6%			
GLASS FIBERS	20.0%	20.0%	20.0%	20.0%	20.0%
DIATOMACEOUS EARTH					6.5%
GROUND OSYTER SHELLS (97.5% CaCO3)	6.5%	6.5%	6.5%	6.5%	
EMULSIFYABLE POLYETHYLENE WAX		2.5%			
STEARIC ACID	1.2%	1.2%	1.2%	1.2%	1.2%
SODIUM BICARBONATE	0.4%	0.4%	0.4%	0.4%	0.4%
DENSITY gm/cc.	0.82	0.86	0.72	0.78	0.75

It will be appreciated that the instant specification and claims are set forth by way of illustration and not limitation, and that various modifications, additions or substitutions may be made without departing from the spirit and scope of the present invention.

CLAIMS:

1. An extrudable composition for making construction material, comprising a dry blend of:

at least 50%, based on total weight of said composition, of a used polyolefinic material derived from residential, commercial, or industrial waste;

about 0.1 to 1.5%, based on the total weight of said composition, of an alkali metal bicarbonate;

in a molar ratio of about 1:1 to 2:1 with respect to said bicarbonate, a saturated fatty acid which is a solid at room temperature, the amount of said alkali metal bicarbonate and said fatty acid being sufficient to form, upon extrusion, a foamed construction material having a specific gravity of 0.4 to 0.9 gm/cc; and

about 2% to 50% of a reinforcing agent.

2. The composition of claim 1 wherein said polyolefinic material is high density polyethylene.

3. The composition of claim 1 wherein the polyolefinic component of said waste polyolefinic material is HDPE, LDPE, LLDPE, UHMWPE, a homopolymer of polypropylene, a copolymer of ethylene and propylene or mixtures thereof.

4. The composition of claim 3 wherein said waste polyolefinic material contains a non-polyolefinic component comprising rigid PVC, flexible PVC, chloro-sulfonated polyethylene, polyamide, polycarbonate, PET thermoplastic

polyester, PBT thermoplastic polyester, ABS, polyphenylene oxide, polyacetal or a mixture thereof.

5. The composition of claim 4 wherein said waste polyolefinic material comprises from about 0.5% to about 20% by weight of said non-polyolefinic component.

6. The composition of claim 1 wherein said fatty acid is selected from the group consisting of myristic acid, palmitic acid, stearic acid, arachidic acid and mixed tallow fatty acid.

7. The composition of claim 1 wherein said alkali metal bicarbonate is sodium bicarbonate or potassium bicarbonate.

8. The composition of claim 1 further comprising:

a filler of calcium carbonate, asbestos, mica, wollastonite, talc, diatomaceous earth, kaolin clays, alumina trihydrates, calcium metasilicate, metal flakes, ceramics, or carbon filaments,

wherein said reinforcing agent is glass fiber.

9. The composition of claim 8 wherein said filler is present in an amount between about 5% to 20% of total weight of said extrudable composition.

10. A foam composition having a specific gravity

of 0.4 to 0.9 gm/cc formed by a continuous extrusion process in the presence of a saturated fatty acid and an alkali metal bicarbonate in a molar ratio of from 1:1 to 2:1 and suitable for use as a substitute for construction lumber, comprising;

at least 50%, based on total weight of said composition, of a used polyolefinic material derived from residential, commercial, or industrial waste; and

an anionic salt of an alkali metal carboxylate of a saturated fatty acid; and

about 2% to 50% of a reinforcing agent.

11. The extruded composition of claim 10 wherein said fatty acid is myristic acid, palmitic acid, stearic acid, arachidic acid or a mixed tallow fatty acid.

12. The extruded composition of claim 10 wherein the polyolefinic component of said waste polyolefinic material is high density polyethylene.

13. The extruded composition of claim 10 further comprising:

a filler of calcium carbonate, asbestos, mica, wollastonite, talc, diatomaceous earth, kaolin clay, alumina trihydrate, calcium metasilicate, metal flakes, ceramics, or carbon filaments,

wherein said reinforcing agent is glass fiber.

14. The extruded composition of claim 10 wherein said alkali metal is sodium or potassium.

15. The extruded composition of claim 10 wherein the polyolefinic component of said waste polyolefinic material is HDPE, LDPE, LLDPE, UHMWPE, a homopolymer of polypropylene, copolymer of ethylene and propylene or mixtures thereof.

16. The extruded composition of claim 15 wherein said waste polyolefinic material contains a non-polyolefinic component comprising rigid PVC, flexible PVC, chloro-sulfonated polyethylene, polyamide, polycarbonate, PET thermoplastic polyester, PBT thermoplastic polyester, ABS, polyphenylene oxide, polyacetal or mixtures thereof.

17. The extruded composition of claim 16 wherein said waste polyolefinic material comprises from about 0.5% to about 20% by weight of said non-polyolefinic component.

18. The extruded composition of claim 13 wherein said filler is present in an amount between about 5% to 20% of total weight of said composition.

19. A method of making a composite foam extruded product which simulates lumber comprising the steps of:

continuously supplying to an extruder used polyolefinic material derived from residential, commercial, or industrial waste;

blending with said polyolefinic material an alkali metal bicarbonate and a saturated fatty acid which is a solid at room temperature, said bicarbonate being at a concentration of about 0.1% to 1.5% of total weight of said blend and said fatty acid being in a molar ratio of from about 1:1 to 2:1 with respect to said bicarbonate and about 2% to 50% of a reinforcing agent;

extruding a melt of said blend through a profile die;

forming a foaming agent and a lubricant for said blend by the in situ reaction of said bicarbonate and said fatty acid;

feeding the lubricated blend from said die into a sizing zone wherein the blend is foamed to substantially its final cross-section;

cooling the thus-foamed material in said sizing zone so as to rigidify the foamed material; and

forcing and pulling the rigidified material through and from said sizing zone.

20. The method of claim 19 further comprising: adding a filler material to said extruder, said filler material being calcium carbonate, asbestos, mica, wollastonite, talc, diatomaceous earth, kaolin clay, alumina trihydrate, calcium metasilicate, metal flakes, ceramics, or carbon filaments and wherein said reinforcing agent is glass fiber.

21. The method of claim 19 wherein said fatty acid is myristic acid, palmitic acid, stearic acid, arachidic acid or a mixed tallow fatty acid.

22. The method of claim 19 wherein said alkali

metal bicarbonate is sodium bicarbonate or potassium bicarbonate.

23. The method of claim 19 wherein the polyolefinic component of said waste polyolefinic material is high density polyethylene.

24. The method of claim 19 wherein the polyolefinic component of said waste polyolefinic material is HDPE, LDPE, LLDPE, UHMWPE, a homopolymer of polypropylene, a copolymer of ethylene and propylene or mixtures thereof.

25. The method of claim 24 wherein said waste polyolefinic material contains a non-polyolefinic component which is a rigid PVC, flexible PVC, chloro-sulfonated polyethylene, polyamide, polycarbonate, PET thermoplastic polyester, PBT thermoplastic polyester, ABS, polyphenylene oxide, polyacetal or a mixture thereof.

26. The method of claim 25 wherein said waste polyolefinic material comprises from about 0.5% to about 20% by weight of said non-polyolefinic component.