CLAIMS

1. A method of converting a carbonaceous feedstock to a syngas-fermentation product, said method comprising:

(a) introducing a carbonaceous feedstock and an oxidant to a gasifier, under suitable gasification conditions to produce a raw syngas stream comprising CO, H_2, and CO_2, wherein said carbonaceous feedstock is selected from the group consisting of biomass, cellulose, hydrocarbons, carbohydrates, coal, petroleum coke, charcoal, lignite, carbon-rich waste materials, natural gas, and combinations thereof, and wherein said oxidant comprises one or more of air, oxygen, and steam;

(b) optionally feeding at least a portion of said raw syngas stream to a syngas-cleanup unit, to produce an intermediate syngas stream;

(c) feeding at least a portion of said raw syngas stream and/or at least a portion of said intermediate syngas stream, if present, to an acid-gas removal unit, to remove at least some of said CO_2 and produce a conditioned syngas stream;

(d) feeding at least a portion of said conditioned syngas stream to a fermentor, under suitable fermentation conditions and in the presence of suitable microorganisms and nutrients to biologically convert one or more of CO, H_2, or CO_2 to a syngas-fermentation product;

(e) capturing a tail gas from an exit of said fermentor, wherein said tail gas comprises at least CO_2 and unconverted CO or H_2;

(f) recycling a first amount of said tail gas to said fermentor in an amount described by R_1, the volumetric ratio of said first amount to said tail gas, wherein R_1 is selected from 0 to 1; and

(g) recycling a second amount of said tail gas to said acid-gas removal unit in an amount described by R_2, the volumetric ratio of said second amount to said tail gas, wherein R_2 is selected from 0 to 1,

wherein R_1+R_2 is greater than 0; and

wherein R_1+R_2 is not greater than 1.

2. The method of claim 1, wherein said gasifier is a fluidized-bed gasifier.

3. The method of claim 1, wherein said acid-gas removal unit additionally removes at least some H_2S, if present.

4. The method of claim 1, wherein said first amount of said tail gas is compressed before being recycled to said fermentor.

5. The method of claim 1, wherein said second amount of said tail gas is compressed before being recycled to said acid-gas removal unit.

6. The method of claim 1, wherein said first amount and said second amount of said tail gas are separately compressed before being recycled to said fermentor and said acid-gas removal unit, respectively.

7. The method of claim 1, wherein the sum R_1+R_2 is selected from about 0.001 to about 0.8.

8. The method of claim 1, wherein CO_2 content in a feed to said fermentor is controlled to a level selected from about 5 vol % to about 50 vol % by adjusting R_1 and/or R_2.

9. The method of claim 1, wherein acid gas molar ratio, $(CO+H_2)/(CO_2+H_2S)$, in a feed to said fermentor is controlled to a value selected from about 2 to about 20.

10. The method of claim 1, wherein R_1 and/or R_2 are adjusted in response to one or more upstream parameters selected from the group consisting of feedstock type, oxidant profile, syngas-generation design or performance, syngas-cleanup design or performance, and acid-gas removal design or performance.

11. The method of claim 1, wherein R_1 and/or R_2 are adjusted in response to one or more fermentor parameters selected from the group consisting of temperature, pressure, residence time, pH, redox potential, nutrient concentration, cell viability, and cell vitality.

12. The method of claim 1, wherein R_1 and/or R_2 are adjusted in response to one or more fermentor variables selected from the group consisting of CO conversion, H_2 conversion, CO_2 conversion, ethanol selectivity, ethanol productivity, ethanol titer, and acetic acid selectivity.

13. The method of claim 4, wherein compressed tail gas recycle increases the pressure within said fermentor, thereby allowing more syngas to enter the liquid phase for bioconversion.

14. The method of claim 1, said method further comprising recycling cells from said fermentor back to said gasifier.

15. The method of claim 1, wherein said tail gas contains between about 2% and about 10% of the syngas contained in said raw syngas stream.

16. The method of claim 1, wherein the total conversion of CO and H_2 is at least 90%.

17. The method of claim 1, wherein the total conversion of CO and H_2 is at least five percentage points higher than total conversion of CO and H_2 that is attained in a comparable method with R_1 and R_2 both equal to 0.

18. The method of claim 17, wherein said total conversion of CO and H_2 is at least ten percentage points higher than total conversion of CO and H_2 that is attained in a comparable method with R_1 and R_2 both equal to 0.

19. The method of claim 1, said method further comprising recovering said syngas-fermentation product from said fermentor.

20. The method of claim 19, wherein said syngas-fermentation product is selected from the group consisting of ethanol, butanol, butyric acid, acetic acid, and combinations thereof.