Energy Thermodynamics of Ethanol Metabolism

This paper will analyze the claim that alcohol (ethanol) provides 7 calories per gram in human metabolism.

Energy Considerations

The reaction from ethanol to carbon dioxide and water is a complex one that proceeds in four steps. The Gibbs Free Energy of Formation (ΔG_f) is shown below for for each step with the ΔG_f values published in the CRC Handbook of Chemistry & Physics. (See http://en.wikipedia.org/wiki/Gibbs_Free_Energy)

Complete Reaction:

C_2H_6O(Ethanol) → C_2H_4O(Acetaldehyde) → $C_2H_4O_2$(acetic Acid) → Acetyl-CoA → $3H_2O + 2CO_2$.

Step One: Ethanol: –174.8 kJ/mol
Ethanal (Acetaldehyde): –127.6 kJ/mol
$\Delta G_{f1} = -127.6 + 174.8 = 47.2$ kJ/mol (Endergonic)
$\Sigma\Delta G_f = 47.2$ kJ/mol (Endergonic)

Step Two: Ethanal: –127.6 kJ/mol
Acetic Acid: –389.9 kJ/mol
$\Delta G_{f2} = -389.9 + 127.6 = -262.3$ kJ/mol (Exergonic)
$\Sigma\Delta G_f = -215.1$ kJ/mol (Exergonic)

Step Three:
Acetic Acid: –389.9 kJ/mol
$3H_2O+2CO_2$: –1500.1 kJ/mol
$\Delta G_{f3} = -1500 + 389.6 = -1110.5$ kJ/mol (Exergonic)
$\Sigma\Delta G_f = -1325.3$ kJ/mol (Exergonic)

Step Four:
We can skip the Acetyl-CoA (Step 4), because the Gibbs energy is a State function, for which themodynamic values are unknown. See http://en.wikipedia.org/wiki/State_function .

Discussion of the calculations:
If catabolism of alcohol goes all the way to completion, then, we have a very exothermic event yielding some **1325.3 kJ/mol** of energy. If the chemical reaction stops part way through the metabolic pathways, as happens when acetic acid is excreted in the urine, then not nearly as much energy can be derived from the alcohol. **The energy yield falls between theoretical lower and upper limits from 215.1 kJ/mol to 1325.3 kJ/mol**. It is also important to note that initiation of Step 1 of this reaction is endothermic, requiring 47.2 kJ per mol of ethanol, or about three molecules of ATP (adenosine triphosphate) required for each molecule of ethanol.

Notes:
The words "alcohol", "ethanol", and "EtOH" are all synonomous for the substance with formula C_2H_5OH.
1.00 mol of EtOH (C_2H_5OH) weighs 46 grams. 46 grams/mol × 7 kcal/gram = 322 kcal/mol. (*7* ***kcal/gm idea***)

1 kilocalorie (kcal) = 4.1868 kiloJoule (kJ). (*Known conversion factors of relevant energy units*)
Since 1 kcal = 4.1868 kJ, then 322 kcal/mol × 4.1868 kJ/kcal ≈ 1348 kJ/mol. The figure of 1348 kJ/mol in this analysis is close to the official maximum theoretical energy yield limit (1325.3 kJ/mol) as shown above.

1325.3 kJ/mol ÷ 4.1868 kJ/kcal = 316.5 kcal/mol. 316.5 kcal/mol ÷ 46 grams/mol = **6.88 kcal/gram**.
Thus the value **7 kcal/gram** is approximately the theoretical maximum energy yield. (*Slightly larger by 1.74%*)
By a similar analysis, the theoretical minimum energy yield is **1.12 kcal/gram**.

1.12 kcal/gram ≤ energy yield of alcohol metabolism ≤ **6.88 kcal/gram**