

Journal of Physics Special Topics

An undergraduate physics journal

P2 3 The Mass-Entropy Relation

J. Fuller, P. Clevely, N. Sowter

Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH

October 31, 2025

Abstract

In this paper, we investigate the local entropy change of The Eucharist, or Holy Communion, comparing the impacts from the use of leavened and unleavened bread and comparing this to the number of church-goers. We find that the impact of unleavened bread on the congregation is greater than the impact of leavened bread, increasing the entropy of the rite significantly with more attendees. We find the total entropy change for Orthodox Christians to be 2.4×10^9 J/K per communion, and for Catholics, the entropy change is 1.3×10^{10} J/K per communion. And the Eucharist is consistent with the laws of thermodynamics.

Introduction

Holy Communion is a rite that is performed in most churches of Christian denominations. The rite involves church-goers and clergy consuming a form of bread and wine, usually a small wafer of bread and a sip of wine or grape juice, as in (1 Corinthians 11:23-25) [1], Jesus Christ proclaims that these are his body and his blood. The spiritual and metaphorical meaning of this is important to all Christians, but some denominations, specifically Catholics [2][3], believe that during Holy Communion, bread and wine literally become the flesh and blood of Christ. It was, in part, the practice of communion that led to the first major schism in the Christian faith, with eastern churches using leavened bread, while western churches preferred to use unleavened bread, with both decisions being based on different theological reasoning [4]. In this paper, we investigate the local entropy change of an eastern and western Holy Communion and compare the results.

Method

To find an entropy change for a Holy Communion, we start by finding the energy change due to the shift in material from bread to flesh. This is expressed as the following:

$$\Delta Q_{bread} = (u_{flesh} - u_{bread})m \quad (1)$$

Where ΔQ_{bread} is the total change in energy. u_{bread} and u_{flesh} are the mass energy densities before and after the transubstantiation, and m is the constant mass of the sample.

A standard unleavened communion wafer has a typical mass of 0.3 g and an energy content of 3682 J [5]. For leavened bread, we take a store-bought bloomer as representative with a 0.3 g sample having an energy content of 2994 J.

Taking the assumption that the mass is unchanged, we then find the energy content of the same mass of flesh. Taking a typical human cell to be representative flesh, we find its molecular composition [6] and take the energy density of flesh as the composition weighted average of the energy densities of the molecular components [7].

Through this, we estimate that flesh has a mass energy density $u_{flesh} = 8000 \text{ J/g}$.

For the energy change of the wine turning to blood, we modify Equation 1 to find our change in terms of volume energy densities σ and constant volume V :

$$\Delta Q_{wine} = (\sigma_{blood} - \sigma_{wine})V \quad (2)$$

From the nutritional information of a bottle of weak, store bought, wine we estimate it to have a volume energy density $\sigma_{wine} = 3290 \text{ J/mL}$ and the energy density of blood is known to be about $\sigma_{blood} = 2929 \text{ J/mL}$ [8]. For a fixed volume of wine V , we assume that a single sip is equivalent to approximately 5 mL.

Summing Equations 1 and 2, we can calculate the total energy change of the bread-flesh and wine-blood systems for a single congregant ΔQ . Doing so, we find that $\Delta Q_{Catholic} = -3.09 \text{ kJ}$ and $\Delta Q_{Orthodox} = -2.4 \text{ kJ}$, and so both transubstantiation reactions are exothermic and energy is released. We can determine the change in temperature in the church ΔT due to a communion with N congregants as [9]:

$$\Delta T = \frac{-N\Delta Q}{C} \quad (3)$$

Where C is the total heat capacity of the environment, if we assume the majority of the heat is transferred to the air and N congregants, then we can express this as [9]:

$$C(N) = \rho_{air}V_{church}c_{air} + Nm_{person}c_{person} \quad (4)$$

where the density of air ρ_{air} [10] and specific heat capacity of air c_{air} [11] are well known, as is true of the heat capacity of a human c_{person} [12]. We estimate the average human mass to be 65 kg and the volume of a church hall to be 500 m^3 [13]

Using our determined temperature change ΔT , and assuming the church can be treated as isobaric, we find the entropy change due to communion as a function of the size of the congregation to be [9]:

$$\Delta S(N) = C(N) \ln \frac{T_0 + \Delta T(N)}{T_0} \quad (5)$$

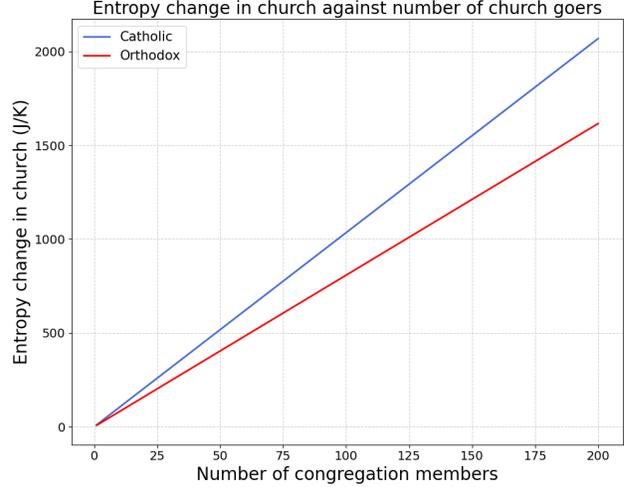


Figure 1: Number of congregation attendees compared to entropy change in J/K. Red represents leavened bread and blue represents unleavened bread. Note that the y-axis ranges from 0 to 2000 and the x-axis has a range 0 to 200, being representative of a standard village church.

Discussion & Conclusion

From the comparison between leavened and unleavened bread in Figure 1, we can see a divergence in the entropic impact of the two different instances of Holy Communion. The unleavened practice leads to a greater local change than that of the leavened practice. With a growing number of congregants, the divergence becomes more noticeable.

Taking into account the total number of Orthodox and Catholic Christians in the world (291,580,000 and 1,272,775,000 respectively) [14], we can find the total entropy change for Orthodox Christians to be $2.4 \times 10^9 \text{ J/K}$ per communion. For Catholics the entropy change is $1.3 \times 10^{10} \text{ J/K}$ per communion.

We note that as transubstantiation occurs, the sacraments become more ordered as they release energy, and there is a small decrease in the entropy, but this does not offset the entropy change from the released heat, and so Holy Communion is consistent with the laws of thermodynamics, namely [9]:

$$\Delta S_{universe} \geq 0 \quad (6)$$

References

- [1] *King James Bible* Cambridge University Press, Cambridge. (Original work published 1769). (1 Corinthians 11:23-25; Luke 22:19-20; Matthew 26:26-28; Mark 14:22-24) (2017)
- [2] United States Conference of Catholic Bishops, *The Eucharist*. Available at: <https://www.usccb.org/eucharist> [Accessed 14/10/2025]
- [3] The Vatican, *Compendium of the Catechism of the Catholic Church* Available at: https://www.vatican.va/archive/compendium_ccc/documents/archive_2005_compendium_ccc_en.html [Accessed 14/10/2025]
- [4] Mitralaxis, Sotiris. 2023. *Fire, Beards, and Bread: Exploring Christian East-West Relations à Propos of Edward Siecienski's (Latest) Work*. Religions 14: 1349. <https://doi.org/10.3390/rel14111349> (2023)
- [5] OC Weekly, *The Nutritional Content of the Holy Communion*. Available at: <https://www.ocweekly.com/the-nutritional-content-of-holy-communion-6618675/> [Accessed 14/10/2025]
- [6] R. A. Freitas Jr, *Nanomedicine, Volume I: Basic Capabilities* Chapter 3, CRC Press, Boca Raton. <https://www.nanomedicine.com/> (2018)
- [7] The Physics Factbook, *Energy Density of Protein* Available at: <https://hypertextbook.com/facts/2003/DavidDukhan.shtml#:~:text=Foods%20like%20carbohydrates%2C%20proteins%2C%20and%20fats%20that%20provide,the%20energy%20density%20of%20fat%20is%209%20cal%2Fg.> [Accessed 14/10/2025]
- [8] CalorieHealthy.com, *Calorie content of blood* Available at: <https://caloriehealthy.com/how-much-calories-is-in-human-blood.html> [Accessed 14/10/2025]
- [9] S. J. Blundell and K. M. Blundell, *Concepts in Thermal Physics* Oxford University Press, Oxford. (2010)
- [10] P. A. Tipler and G. Mosca, *Physics for Scientists and Engineers* Freeman, New York (2007)
- [11] The Engineering toolbox, *Specific heat capacity of air: Isobaric and Ischoric heat capacities at various temperatures and pressures*. Available at: https://www.engineeringtoolbox.com/air-specific-heat-capacity-d_705.html
- [12] X., Xu, T. P. Rioux and M. P. Castellani. *The specific heat of the human body is lower than previously believed* Temperature, 10(2), 235-239. <https://doi.org/10.1080/23328940.2022.2088034> (2022)
- [13] Warlingham Church Hall, *Floor plan and details* Available at: https://warlingham.bluekeyprojects.co.uk/wp/?page_id=2 [Accessed 14/10/25]
- [14] gordenconwell.edu *Status of global Christianity 2025* Available at: <https://www.gordenconwell.edu/wp-content/uploads/sites/13/2025/01/Status-of-Global-Christianity-2025.pdf> [Accessed 14/10/2025]