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Energy accuracy of nutritional fluids provided in hospital: comparing nutrition label values against direct bomb calorimetry

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Research Article

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Abbreviation:
EN, enteral nutrition; FSANZ, Food Standards Australia New Zealand; GE, gross energy; IDDSI, International Dysphagia Diet Standardisation Initiative; IV, intravenous; ME, metabolisable energy; NIP, nutrition information panel; ONS, oral nutrition supplements; PN, parenteral nutrition

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Abstract

Mandatory thresholds for the accuracy of reported energy on food and beverage product labels do not exist in many countries. Accurate nutrition information is essential for ensuring nutritional adequacy among hospital patients. The aim of this study was to compare direct measures of energy of nutritional fluids provided in hospitals to values determined via manufacturers' specifications. Nutritional fluids were identified as any liquid provided to hospital patients orally, enterally or parenterally, to deliver nutrition. These were categorised into six groups aligned to food/medical standards, including (1) local recipes, (2) pre-packaged general fluids, (3) supplementary fluids, (4) prescribed nutrition fluids – thickened, (5) prescribed nutrition fluids – oral/enteral and (6) prescribed medical nutrition – intravenous (IV) and parenteral. An equivalence testing statistical approach (±10 % thresholds) was used to compare energy values derived directly via bomb calorimetry against those obtained from manufacturer specifications. A total of sixty-nine fluids were measured. One-fifth (*n* 14) exhibited non-equivalent energy values, with the majority of these (*n* 11; 79 %) likely to contain less energy than that calculated from reported values. Almost all (34/35; 97 %) prescribed nutrition fluids (oral/enteral (20/20; 100 %), IV and parenteral (7/7; 100 %) and thickened fluid (7/8; 88 %) products were equivalent. In contrast, only 21/34 (62 %) non-prescribed fluids (local recipes (2/11; 18 %), supplementary fluids (4/5; 80 %) and pre-packaged general fluid (15/18; 83 %) products) demonstrated equivalence. Energy content of nutritional fluids prescribed to hospital patients typically aligns with manufacturers' values. Consumption of non-prescribed fluids may result in lower energy intakes than expected.

Hospital patients often have increased energy needs due to acute or chronic illness[1,2]. Nutritional fluids (i.e. oral, enteral, parenteral) may be used as a first-line intervention to feed individuals who are critically ill or nutritionally compromised[3–5]. Healthcare professionals rely on the nutrition information panel (NIP) of products to ensure patients are provided with sufficient calories to meet their estimated requirements[1]. Inaccurate calorie values could expose patients to risks associated with under- and over-feeding.

Nutritional fluids provided in hospitals vary in composition, with some classified as foods while others are considered medicines. In Australia, Food Standards Australia New Zealand (FSANZ) regulate fluids that are consumed orally (including clinically prescribed oral nutrition supplements, ONS) or delivered enterally via tube feeding (e.g. enteral nutrition; EN). On the other hand, the therapeutic goods administration is responsible for the governance of medically prescribed intravenous (IV) fluids and parenteral nutrition (PN). Mandatory thresholds for the accuracy of reported energy on food and beverage product labels in Australia do not exist[6]. This resonates with other regions throughout the world, including the European Union[7], Canada[8] and UK[9]. FSANZ stipulates that packaged products must contain an NIP, which includes information outlining the average energy content (kJ) for both a serving and unit quantity of the food[6,10]. Reported energy values can be estimated either by a summation of the energy contained within each macronutrient (FSANZ Schedule 11), or obtained from a comparable item listed in the Australian Food Composition Database[11]. Therapeutic goods administration conveys that when a medicine is intended for use as an energy source it must display an energy (kJ) equivalent for the stated volume[12]. Without a direct measure of the energy content, stated values have the potential to misrepresent the actual energy contained within a fluid.

Bomb calorimetry provides a method for directly ascertaining the maximum energy content of food (i.e. gross energy, GE), and via energy conversion factors, can be used to verify energy values (i.e. metabolisable energy, ME) reported on food labels[13,14]. Standardised food/fluid sample preparation methods and combustion procedures have been developed to ensure bomb calorimetry is performed reliably and accurately[15]. Measured values can then be assessed

against reported values and equivalence determined by comparing them to predetermined thresholds.

The aim of this study was to quantify the energy from different nutritional fluids provided in hospitals via bomb calorimetry and compare these to values determined from manufacturers' specifications (i.e. NIP). Results will indicate the extent to which current food and medical standards support the accurate quantification of energy by manufacturers of fluids supplied to vulnerable populations.

Materials and methods

Study overview

This study employed a statistical approach to determining equivalence[16] between measured (via bomb calorimetry) and reported energy in nutritional fluids available at a major tertiary hospital (750 beds) in Queensland, Australia. Predetermined equivalence thresholds of ±10 % were employed for all comparisons. Reported GE values determined from products' NIP or from the hospital's electronic food service system were calculated. Fluids then underwent direct caloric measurement via bomb calorimetry to establish a mean ± 90 % CI GE value. Reported values were considered 'equivalent' to measured values when the established ±90 % CI fell within the ±10 % thresholds[16,17].

Nutritional fluids provided in hospital

Nutritional fluids were defined as any liquid provided to patients orally, enterally or parenterally, to deliver nutrition. This included items available on the hospital's 'Free Fluids' diet (i.e. any item that is a smooth liquid, with no lumps or pieces), including products classified by the International Dysphagia Diet Standardisation Initiative (IDDSI) framework as being a 'drink' (i.e. thin and thickened fluids)[18], as well as clinician (e.g. dietitian) prescribed ONS and EN. Medical practitioner prescribed fluids, where the intention was for use as an energy source (i.e. IV and PN), were also included. Fluids were categorised according to FSANZ standards[6,19,20] and therapeutic goods administration criteria[21] as described in Table 1. A complete list of manufacturer names and brands for all items analysed is provided in Supporting Information (File S1 – Manufacturer Names). Items were further identified according to major product constituents, including milk, nut/seed, juice and sugar (i.e. made from predominantly added carbohydrate/sugars) based fluids.

Serving size (weight)

Nutritional fluids were available in either single-serve (i.e. tetra pack, EN/PN bag) or multi-serve (e.g. cordial bottle, decanted juice) packages. Items were weighed prior to decanting the fluid and the package weight was subtracted from the gross weight to ascertain net fluid weight (g). If packages contained multiple serves, fluid weight was divided by the number of serves declared on the NIP to provide serving size weight. To assess serving size consistency, five to six single-serve items from within each of the five oral/enteral fluid classifications were weighed (including packaging), and the CV was determined.

Establishing equivalence thresholds

The absence of mandated tolerance levels for energy accuracy on food and beverage product labels in Australia necessitated *a priori* consideration of an appropriate equivalence margin. Initially, the US Food and Drug Administration ±20 % tolerance level was considered[22]. However, this threshold was deemed too lenient given the importance of accurate energy prescriptions/intake for hospital patients. As such, a more conservative ±10 % threshold was employed as a 'consensus criteria' based on the expert opinion of the Food Regulation Policy Advocacy Working Group of Dietitians Australia (personal communication).

Calorimetry sample preparation

Calorimetry sample preparation followed the principles outlined by Hopper et al. (2024)[15]. Fluids were first agitated for ~60 s, and then a sample (~20 g) of each was measured on an analytical balance (Ohaus AX324, Ohaus Corporation) before being poured into a silicone mould. Samples were then dehydrated by oven-drying (LT28 500W 6-layer) at 70°C for 72 h, or until a constant weight was achieved (n.b., PN – protein component ~120 h). Dehydrated samples were homogenised using a mortar and pestle. A pellet press (MTB12 Micro-tec, Haarlem, Netherlands) was then used to form ~1 g samples from the homogenised powder. Liquids that initially came in the form of a dry powder (i.e. supplement powders requiring water for consumption) were immediately pelletised. Initially, three pellets were combusted for each fluid using an oxygen bomb calorimeter (DDS CAL3K-S, Digital Data Systems), following the manufacturers calibration (Benzoic acid) and operational instructions[23]. Calibration was performed at the beginning of each day and after 15 combustions, or when the ambient temperature changed by greater than 2. If within-sample test differences for fluid pellets were > 0·5 kJ/g, or if the 90 % CI of the averaged data approached an equivalence margin, up to two additional pellets were combusted.

Gross energy calculation

Energy values reported on the NIP and electronic food service system database represent ME[11]. This requires conversion to GE to permit comparison against values that are directly measured. GE values of fluids were established using the following calculation:

$$GE_{kJ} = \Sigma_{W_i \times F_i}^{N}$$

where GE_{kJ} is the total GE per serve, N is the number of energy-contributing constituents per serve of fluid, W_i is the weight of each macronutrient per serve of the fluid item and F_i represents the GE factors for each energy-providing constituent (i.e. fat = 39 kJ/g, protein = 23 kJ/g and all carbohydrates including fibre = 17 kJ/g[13,24,25]). GE calculations assumed items contained the reported macronutrients (i.e. fat, protein, carbohydrate) per serve (g) as stated on the NIP (packaged items) or electronic food service system database (local recipes). Total E_{kJ} was divided by serving size actual weight (g) to provide kJ/g.

Gross energy measurement

GE values determined via bomb calorimetry were established using the following calculation:

$$\frac{M_d}{M_w} \times \varepsilon_i = \varepsilon_f$$

where ε_f is the energy density (kJ/g) of the beverage (prior to dehydration), M_d is the dry mass of the sample, M_w is the wet

Table 1. Food and medical nutrition classifications of nutritional fluids using FSANZ and TGA criteria

Fluid classification	Food/medical standard	Product/label specifications	Examples
1. Local Recipe	FSANZ Standard 1.2.8 – Nutrition information requirements[6]	Average energy (kJ) content	Locally decanted/prepared juice, cordial, soup, custard, jelly etc
2. Pre-packaged general fluids	FSANZ Standard 1.2.8 – Nutrition information requirements[6]	Average energy (kJ) content	Pre-packaged beverages (milk, juice, soft drink, custard, yoghurt etc.) as available in supermarkets
3. Supplementary fluids	FSANZ Standard 2.9.3 – Formulated meal replacements and supplementary food[19]	FMR: ≥ 850 kJ/serve SF: ≥ 550 kJ/serve	Supermarket-based (a) meal replacements and (b) supplementary foods
4. Prescribed nutrition fluids – thickened	FSANZ Standard 2.9.5 – Foods for special medical purposes[20]	Prescribed only by Medical Practitioner or Speech Pathologist Minimum or average energy (kJ) content	Thickened fluids prescribed for dysphagia
5. Prescribed Nutrition Fluids – ONS/EN	FSANZ Standard 2.9.5 – Foods for special medical purposes[20]	Prescribed only by Medical Practitioner or Dietitian. Minimum or average energy (kJ) content	Oral nutrition supplements, enteral nutrition
6. Prescribed Medical Nutrition – IV/PN	TGA Order No. 91 – Standard for labels of prescription and related medicines[21].	Prescribed only by Medical Practitioner and intended for use as an energy source. Energy (kJ) equivalent of the stated volume	Parenteral nutrition, intravenous fluids

FSANZ, Food Standards Australia New Zealand; ONS, oral nutrition supplements; EN, enteral nutrition; FMR, formulated meal replacement; SF, supplementary food; IV, intravenous; PN, parenteral nutrition; TGA, therapeutic goods administration.

Table 2. Serving size consistency summary

Fluid classification	*n*	CV (%)
Local recipes	25	3·4
Pre-packaged general fluids	25	0·6
Supplementary fluids	25	0·6
Prescribed nutrition fluids – thickened	25	0·8
Prescribed nutrition fluids – ONS/EN	30	0·3

EN, enteral nutrition; ONS, oral nutrition supplements.

(initial) mass of the sample and ε_i is the energy density (kJ/g) of the dry sample (determined by calorimeter combustion).

Statistical analysis

Data were initially entered into a Microsoft Excel (Microsoft, Office 365™) spreadsheet. The mean % difference (Mean Δ) for measured *v.* label comparison (i.e. kJ/g) and 90 % CI were calculated in the Excel sheet (by imputing appropriate formula functions) for each test fluid to determine equivalence (i.e. the 90 % CI fits within the established equivalence margins), and the 95 % CI was used to test the null hypothesis (i.e. no statistical difference when the 95 % CI crosses zero, $P > 0{\cdot}05$). When the 90 % CI of the Mean Δ extended beyond the established equivalence margins (i.e. ±10 %), this was interpreted as measured *v.* label comparisons being non-equivalent, in accordance with Lakens[16]. Equivalence plot figures were produced using RStudio™[26], with the 'ggplot2' package[27].

Results

Serving size (weight) consistency

In total, 130 samples were assessed for serving size consistency (i.e. five serves each from five to six items within each oral/enteral fluid classification). Overall, the CV ranged from 3·4 % (local recipes) to 0·3 % (prescribed nutrition fluids – ONS/EN) as per Table 2. A comprehensive list of weight variation for all items analysed is provided in Supporting Information (File S2 – serving size consistency).

Gross energy – reported v. measured

GE was measured for seventy-three fluids. Samples consisted of sixty-two commercially manufactured items displaying a NIP and eleven locally produced recipes for which nutrition information was derived from an electronic food service system database. Four items were excluded due to containing sugar alcohols (erythritol, *n* 2) and fatty acids (*n* 2). Accurate GE comparisons for these products could not be attained due to manufacturers not listing sugar alcohol amounts on their NIP and inability to successfully dehydrate products containing fatty acids. A summary of included fluids (*n* 69) and classifications outlining statistical equivalence (±10 %) is provided in Table 3. A detailed list of results for all individual products is provided in Supporting Information (File S3 – Results Table).

When compared with the ±10 % equivalence margin, 80 % (*n* 55) of fluids demonstrated statistical equivalence. Of the fourteen products whose energy content was deemed *non-equivalent* to the NIP, most (*n* 11; 79 %) contained fewer kilojoules than that calculated from manufacturer's reports.

Food and medical nutrition classifications

Local recipes were the least equivalent nutritional fluid classification (*n* 2; 18 %). Supplementary fluids (*n* 4; 80 %), pre-packaged general fluids (*n* 15; 84 %) and prescribed thickened fluids (*n* 7; 88 %) all had equivalence outcomes over four times greater. Prescribed ONS/EN (*n* 20; 100 %) and prescribed IV/PN (*n* 7; 100 %) all contained calories considered equivalent to that calculated from manufacturers reports. Equivalence plots relevant to each fluid classification are displayed in Figure 1.

Table 3. Reported *v.* measured energy accuracy of nutritional fluid categories

Fluid classification	*n*	Number of items demonstrating statistical equivalence (±10 %) n (%)
All included items	69	55 (80 %)
1. Local recipes	11	2 (18 %)
2. Pre-packaged general fluids	18	15 (84 %)
3. Supplementary fluids	5	4 (80 %)
4. Prescribed nutrition fluids – thickened	8	7 (88 %)
5. Prescribed nutrition fluids – ONS and EN	20	20 (100 %)
6. Prescribed medical nutrition – IV and PN	7	7 (100 %)
Product constituents		
Milk-based	42	38 (90 %)
Juice-based	12	6 (50 %)
Nut/seed-based	4	2 (50 %)
Sugar-based	4	2 (50 %)

ONS, oral nutrition supplements; EN, enteral nutrition; IV, intravenous; PN, parenteral nutrition.

Product constituents – milk/juice/nut/seed/sugar-based

Milk-based samples most often met the equivalence criteria (*n* 38; 90 %), whereas all other items (i.e. juice/nut/seed/sugar-based) exhibited equivalence in only 50 % of cases.

Discussion

This study quantified the energy content of different nutritional fluids available at a major tertiary hospital, comparing values derived directly via bomb calorimetry against those determined from manufacturers' reported values. Non-equivalence between reported and measured calorie values was identified for items across most fluid categories (except for prescribed ONS/EN and IV/PN) but was more common in non-prescribed fluids (e.g. locally prepared recipes). Results suggest that a direct measure of energy may be required for some hospital fluid categories to ensure accurate calorie provision for vulnerable patients.

The current analysis indicated that one-fifth of nutritional fluid products provided to patients at a large tertiary hospital exhibited non-equivalent energy values (i.e. 90 % CI crossed the ±10 % threshold). Previous research suggests that the reported energy content of foods and beverages can differ from directly measured values by up to 85 %[14,28–31]. Greater magnitude of difference tends to occur when items are locally produced (i.e. restaurant, take away kitchen, or café) compared with those generated on a larger national and commercial scale[14,29,30,32]. Local recipes can be prone to larger differences due to increased instances of human error (e.g. inaccurate recipe formulation)[29,30,32]. However, evidence suggests that large-scale pre-packaged food producers still often underestimate reported energy despite improved processes and efforts for standardisation[14,33]. The current study indicates that approximately 80 % of all non-equivalent outcomes comprised energy levels under the reported value, whereby locally produced recipes did in fact exhibit the greatest energy variation. Conversely, pre-packaged prescribed nutrition fluids (ONS/EN) and medical nutrition fluids (IV/PN) displayed the most accurate energy values, with all items demonstrating statistical equivalence.

Fluids governed by a food/medical standard and requiring clinician prescription (i.e. FSANZ Standard 2·9·5[20] and therapeutic goods administration Order No. 91[21]) were typically more accurate (i.e. statistically equivalent) than those not meeting these criteria (i.e. FSANZ Standard 1.2.8[6] and 2.9.3[19]). Accuracy was greater for prescribed nutrition fluids (i.e. ONS/EN) where product consistency was regulated (e.g. milk-based). In Australia, milk composition is governed by FSANZ (Standard 2.5.1[34]), which permits manufacturers to add or withdraw milk components (such as fat) to standardise milk composition as a means of producing nutritionally consistent products. In contrast, juice and nut/seed beverages are regulated according to a different standard (i.e. FSANZ Standard 2.6.1[35]) with less emphasis on product consistency. As such, fruit and nut/seed-based items assessed in this study were least likely to demonstrate equivalence, typically containing less energy than reported. Fruit and nut energy levels can vary based on season[36], ripening[37–39], climate[40] and maturity[41]. With a lack of nutrient and energy regularity in unformulated raw produce, these fluids may be prone to higher levels of energy variation and inaccuracy.

Despite being categorised as a prescribed nutrition fluid, thickened fluids demonstrated a slightly lower likelihood of equivalence (88 %) compared with ONS/EN and IV/PN products (100 %). Thickening agents listed as ingredients (e.g. guar and tara gums) contain organic compounds such as acetic and pyruvic acid, which have unique FSANZ GE factors (i.e. 13 kJ/g[11]). It is unclear how much these compounds impact reported ME values, as amounts (g) for these are not specified on the NIP. Energy values were unable to be accounted for with these compounds when calculating GE. Further research determining the impact of thickening agents on reported energy provision is required.

Clinical implications and suitability of current standards

While some food and medical nutrition labelling standards may facilitate accurate energy provision of hospital nutrition fluids, others may not. A lack of defined thresholds for food and beverage energy reporting may ultimately lead to inaccurate determination of energy provision to patients in Australian hospitals. As the majority of non-equivalent fluids tested in this study contained less energy than reported on the product's NIP, the inadequate dietary provision (and intakes) of hospitalised patients previously reported within our facility[42] may have been underestimated. Possibly more apparent among patients whose intakes consist largely of locally prepared recipes and pre-packaged fluids that are juice or nut/seed-based. This can potentially lead to clinically meaningful variances in energy intake, examples of which have been demonstrated in a previous study whereby a ~12 % reduction in the total calorie provision/day was observed when the non-equivalent measured energy value replaced NIP-derived ME values[43]. Mandating energy accuracy thresholds may present an opportunity to ensure all food and beverage items (not just prescription-based fluids) provide accurate nutrition label information. Although generous, the US Food and Drug Administration has a threshold for allowable energy variation of ±20 %[22]. The mere presence of this mandatory regulation may facilitate hospitals' and clinicians' ability to provide sufficient

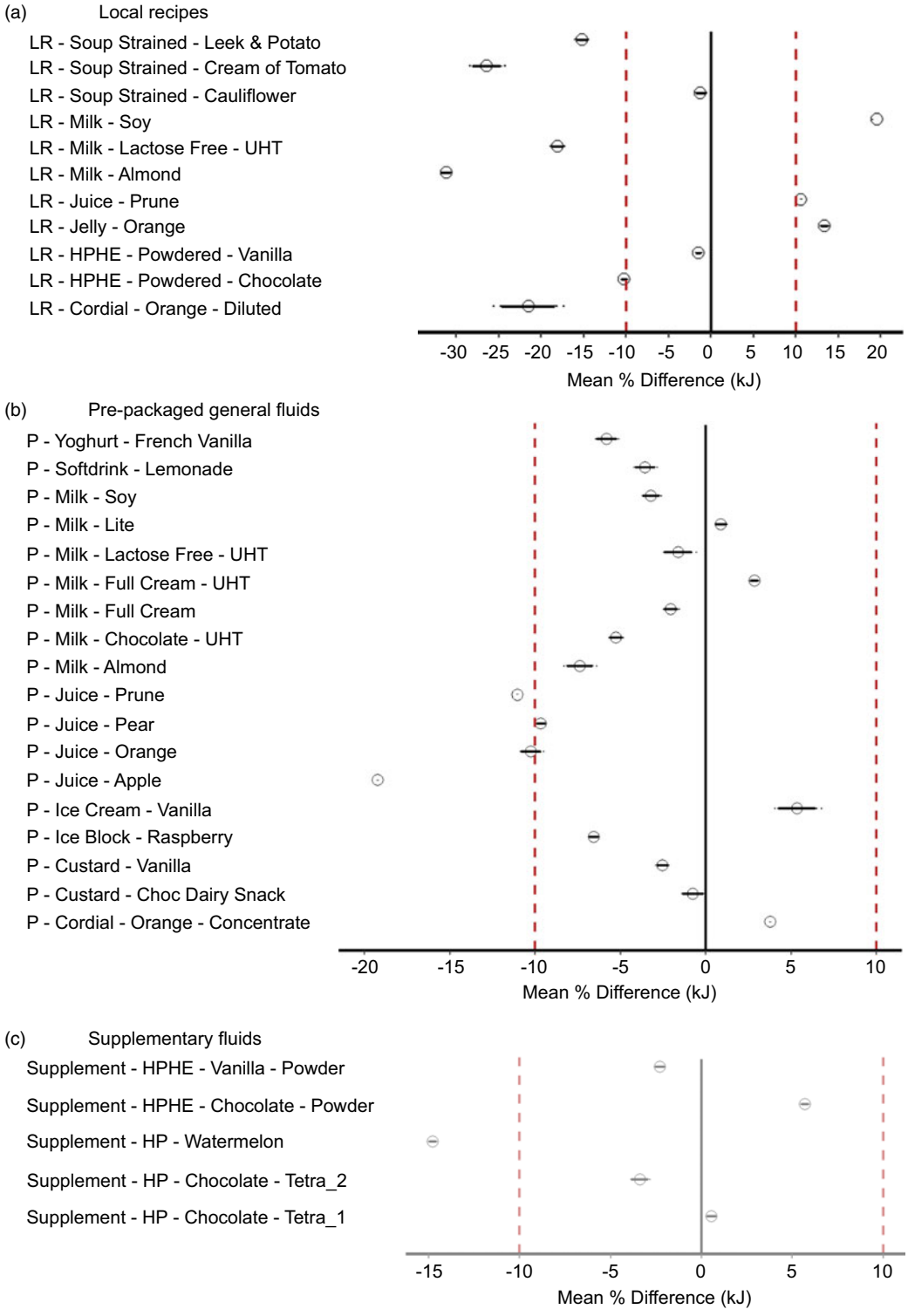

Figure 1. Local recipes (a), pre-packaged general fluids (b), supplementary fluids (c), prescribed nutrition fluids – thickened (d), prescribed nutrition fluids – ONS and EN, (e) and prescribed medical nutrition – IV and PN and (f) directly measured (bomb calorimetry) *v*. food label energy comparison (Mean Δ (centre), 90 % CI (thick error bars) and 95 % CI (dashed thin error bars)). All measured values (mean ± 90 % CI) are normalised to the energy value reported from manufacturers' specifications using the nutrition information panel (0). ONS, oral nutrition supplements; EN, enteral nutrition; IV, intravenous; PN, parenteral nutrition.

nutrition to meet patient energy needs. This could be a consideration for other countries, however, associated implications such as manufacturer costs[13] and willingness to undertake additional product testing remain relatively unexplored. Establishing thresholds and the impact of associated changes is likely to require further industry and stakeholder consideration. Ultimately, hospitals could achieve improved energy accuracy if menu items supplied under food service contracts were mandated to undergo independent testing for direct determination of calorie content.

Reported energy values – additional sources of error

FSANZ indicates reported energy values for food/fluids to be estimated either by a summation of the ME contained within each macronutrient, or obtained from a comparable item listed in the

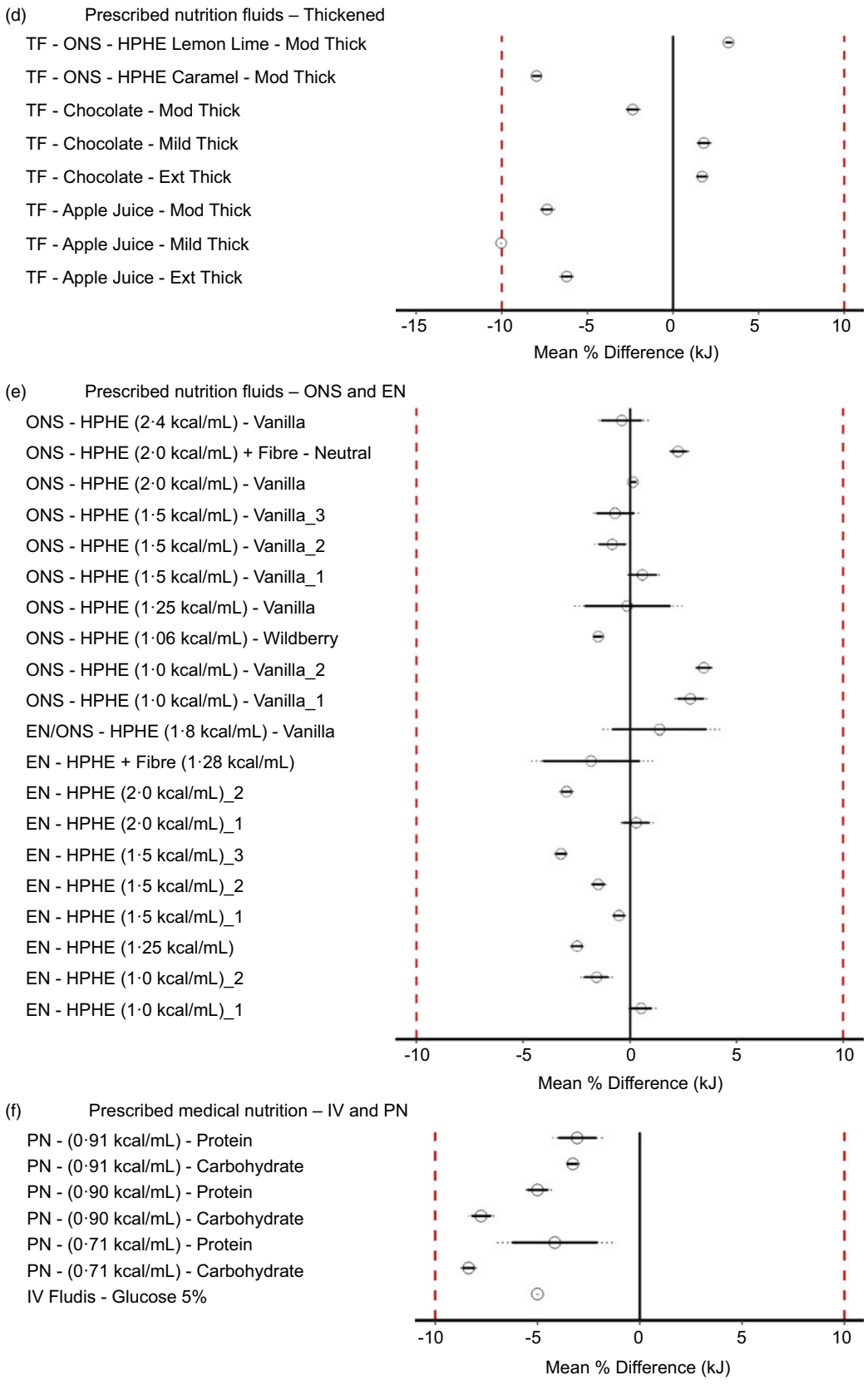

Figure 1. (*Continued*).

Australian Food Composition Database[11]. However, macronutrient and total energy values can vary based on the methods used to quantify the composition of the food/fluid[44], or constraints associated with the scope of products included within publicly available nutrition databases[45]. Previous research suggests that energy underestimation is prominent in nutrition databases[31,46]. Foods and beverages listed in databases often display energy and macronutrient values based on averages taken

from multiple samples (i.e. different brands), whereby individual values for each sample may differ. Without a direct measure of energy content, reported values, either via calculation or food databases, may misrepresent the actual energy contained within a food/beverage item.

Energy provision may also be influenced by variability in serving size, whereby serving size variation (CV) in this study ranged from 0·3 % (prescribed nutrition fluids – ONS/EN) to 3·4 % (local recipes). Research indicates local recipes (i.e. restaurant meals and takeaway items) are likely to have weight discrepancies[29,30,32,46,47] compared with pre-packaged items[48]. Reduced variation within packaged fluids implies patients are likely to be provided with correct portions and nutritional values for these products. Improved weight consistency (and energy accuracy) may be achieved if hospital menus primarily consist of pre-packaged items rather than locally produced/decanted products. However, this may have financial and environmental implications that hospitals should consider.

Gross energy measurement – challenges

Due to the scope of this investigation, outcomes were only measured for one item relevant to each hospital nutrition fluid analysed. As such, factors such as seasonal variation, batch production variability and manufacturing location differences were not examined. Combustion of erythritol (sugar alcohol) containing products also exhibited considerable energy variation (i.e. reported *v.* measured = +19 %). While dietary erythritol has a GE content of 17·2 kJ/g[49], the ME value has been estimated to be less than 1·7 kJ/g[50]. The label value assigned by FSANZ is 1 kJ/g[11] (i.e. ~95 % less than sugar and other carbohydrates). Accurate energy comparison for these products could not be attained because manufacturers did not list the amounts of these compounds on their NIP.

The inability to fully dehydrate fatty acids successfully has been documented when undertaking lyophilisation, relating to structural membrane properties causing increased integrity and resistance to freezing[51–54]. This may also occur with oven-drying, with outcomes from this study indicating fluids containing fatty acids (e.g. mixed PN) were unable to be dehydrated (and combusted) completely, even after 5 days of dehydration. Label comparison results for these samples were therefore considered inaccurate. As a result, protein and carbohydrate PN chambers were dehydrated and analysed separately for this study. Further research is required to assess the impact of successfully dehydrating fatty acids for bomb calorimetry.

Conclusion

Current food labelling requirements in many countries, including Australia, provide limited imperative (i.e. mandatory thresholds) for food manufacturers to ensure accurate energy values are represented on NIP. This study determined that the reported energy value of nutritional fluids provided in hospitals can at times be non-equivalent (and lower) than the actual measured value. This is especially relevant for non-prescribed fluids, such as locally prepared recipes and fluids consisting of predominantly raw produce (such as fruit, nuts and seed additives). Fewer inaccuracies were evident among nutrition fluids governed by a food or medical standard dictating clinical prescription and/or product formulation. The direct measurement of the energy density of locally prepared hospital nutritional fluids is recommended to ensure appropriate energy provision to patients.

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The authors affirm that this manuscript is an honest, accurate and transparent account of the study being reported. No important aspects of the study have been omitted and any discrepancies from the study as planned have been described.

Supplementary material. For supplementary material/s referred to in this article, please visit https://doi.org/10.1017/S0007114525000601

References

1. Lochs H, Dejong C, Hammarqvist F, *et al.* (2006) ESPEN Guidelines on Enteral Nutrition: gastroenterology. *Clin Nutr* **25**, 260–274.
2. Thibault R, Abbasoglu O, Ioannou E, *et al.* (2021) ESPEN guideline on hospital nutrition. *Clin Nutr* **40**, 5684–5709.
3. Australian Commission on Safety and Quality in Health Care (2018) *Hospital-Acquired Complication 13 - Malnutrition*. Selected Best Practices. Sydney, NSW, Australia: ACSQHC.
4. Elia M, Normand C, Norman K, *et al.* (2016) A systematic review of the cost and cost effectiveness of using standard oral nutritional supplements in the hospital setting. *Clin Nutr* **35**, 370–380.
5. Cawood AL, Elia M & Stratton RJ (2012) Systematic review and meta-analysis of the effects of high protein oral nutritional supplements. *Ageing Res Rev* **11**, 278–296.
6. Food Standards Australia New Zealand (2016) *Nutrition Information Requirements*, vol. Standard 1.2.8, pp. 1–9. Canberra, ACT, Australia: FSANZ.
7. Codex-Alimentarius (2021) Guidelines on Nutrition Labelling: United Nation's Food and Agriculture Organization and the World Health Organization. https://www.fao.org/fao-who-codexalimentarius/thematic-areas/nutrition-labelling/en/ (accessed 10 January 2023).
8. Government of Canada (2022) Food and Drug Regulations—C.R.C. 870. https://canlii.ca/t/55lwr (accessed 05 January 2023).
9. Public Health England (2011) *SACN Dietary Reference Values for Energy*. England: PHE.
10. Australian Government (2019) *Legislation Act 2003. No. 139*, pp. 1–101. Canberra, ACT, Australia: Office of Parliamentary Counsel.
11. Food Standards Australia New Zealand (2016) *Calculation of Values for Nutrition Information Panel*, vol. Schedule 11, pp. 1–3. Canberra, ACT, Australia: FSANZ.
12. Therapeutic Goods Administration (2023) Therapeutic Goods Administration. https://www.tga.gov.au/ (accessed 11 January 2023).
13. FAO/WHO/UN Expert Committee (2004) *Human Energy Requirements: Report of a Joint FAO/WHO/UNU Expert Consultation*. FAO Food and Nutrition Paper, 0254–4725;77 no. 9251052123. Rome: Food and Agriculture Organization of the United Nations.
14. Allison DB, Heshka S, Sepulveda D, *et al.* (1993) Counting calories—caveat emptor. *JAMA* **270**, 1454–1456.
15. Hopper Z, Desbrow B, Roberts S, *et al.* (2024) Beverage sample preparation and procedures for bomb calorimetry: establishing equivalency in methods. *J Food Compost Anal* **128**, 106033.
16. Lakens D (2017) Equivalence tests: a practical primer for *t* tests, correlations, and meta-analyses. *Soc Psychol Personal Sci* **8**, 355–362.
17. Walker E & Nowacki AS (2011) Understanding equivalence and noninferiority testing. *J Gen Intern Med* **26**, 192–196.
18. International Dysphagia Diet Standardisation Inititative (2019) *Complete IDDSI Framework Detailed Definitions 2.0*, pp. 1–26. United States of America: IDDSI.

19. Food Standards Australia New Zealand (2016) *Formulated Meal Replacements and Formulated Supplementary Foods*, vol. Standard 2.9.3. Canberra, ACT, Australia: FSANZ.
20. Food Standards Australia New Zealand (2016) *Food for Special Medical Purposes*, vol. Standard 2.9.5, pp. 1–7. Canberra, ACT, Australia: FSANZ.
21. Therapeutic Goods Administration (2016) *Standard for Labels of Prescription and Related Medicines*, vol. Therapeutic Goods Order No. 91. Woden, ACT, Australia: Department of Health and Aged Care, Australian Government.
22. US FDA Department of Health and Human Services (2008) *Code of Federal Regulations - Food Labeling*, vol. Title 21. Washington, DC: US Government Printing Office.
23. Digital Data Systems (2020) *Cal3K-S Operations Manual V5.1*, pp. 1–52. Gauteng, South Africa: DDS.
24. Capuano E, Oliviero T, Fogliano V, *et al.* (2018) Role of the food matrix and digestion on calculation of the actual energy content of food. *Nutr Rev* **76**, 274–289.
25. Atwater WO & Benedict FG (1902) Experiments on the metabolism of matter and energy in the human body. *US Office Exp Stations Bull* **109**, 1898–1900.
26. R Core Team (2023) *R: A Language and Environment for Statistical Computing. R Core Team*. Vienna, Austria: R Foundation for Statistical Computing.
27. Wickham H (2016) *ggplot2: Elegant Graphics for Data Analysis*. New York: Springer-Verlag.
28. Root AD, Toma RB, Frank GC, *et al.* (2004) Meals identified as healthy choices on restaurant menus: an evaluation of accuracy. *Int J Food Sci Nutr* **55**, 449–454.
29. Urban LE, Weber JL, Heyman MB, *et al.* (2016) Energy contents of frequently ordered restaurant meals and comparison with human energy requirements and US Department of Agriculture Database Information: a multisite randomized study. *J Acad Nutr Diet* **116**, 590–598.
30. Urban LE, McCrory MA, Dallal GE, *et al.* (2011) Accuracy of stated energy contents of restaurant foods. *JAMA* **306**, 287–293.
31. Basolo A, Parrington S, Ando T, *et al.* (2020) Procedures for measuring excreted and ingested calories to assess nutrient absorption using bomb calorimetry. *Obesity* **28**, 2315–2322.
32. Urban LE, Dallal GE, Robinson LM, *et al.* (2010) The accuracy of stated energy contents of reduced-energy, commercially prepared foods. *J Am Diet Assoc* **110**, 116–123.
33. Jumpertz R, Venti CA, Le DS, *et al.* (2013) Food label accuracy of common snack foods. *Obesity* **21**, 164–169.
34. Food Standards Australia New Zealand (2016) *Milk*, vol. Standard 2.5.1. Canberra, ACT, Australia: FSANZ.
35. Food Standards Australia New Zealand (2016) *Fruit Juice and Vegetable Juice*, vol. Standard 2.6.1. Canberra, ACT, Australia: FSANZ.
36. Eriksson O & Ehrlén J (1991) Phenological variation in fruit characteristics in vertebrate-dispersed plants. *Oecologia* **86**, 463–470.
37. Gautier H, Diakou-Verdin V, Bénard C, *et al.* (2008) how does tomato quality (sugar, acid, and nutritional quality) vary with ripening stage, temperature, and irradiance? *J Agric Food Chem* **56**, 1241–1250.
38. Liu Y, Liu S, Huo G, *et al.* (2000) Seasonal variation of the amounts of some mineral elements and nutrition concentration during the development course of sweet persimmon fruit. *Acta Agric Univ Jiangxiensis* **22**, 265–270.
39. Adrian JAL, Arancon NQ, Mathews BW, *et al.* (2012) Proximate Analysis, *in vitro* organic matter digestibility, and energy content of common guava (Psidium guajava L.) and yellow, strawberry guava (Psidium cattleianum Var. lucidum) tree parts and fruits as potential forage. *J Agr Food Chem* **60**, 10398–10405.
40. Rabadán A, Álvarez-Ortí M & Pardo JE (2019) A comparison of the effect of genotype and weather conditions on the nutritional composition of most important commercial nuts. *Sci Hortic* **244**, 218–224.
41. Song Y, Rowland DL, Tillman BL, *et al.* (2022) Impact of seed maturity on season-long physiological performance and offspring seed quality in peanut (Arachis hypogaea L.). *Field Crop Res* **288**, 108674.
42. Roberts S, Chaboyer W, Leveritt M, *et al.* (2014) Nutritional intakes of patients at risk of pressure ulcers in the clinical setting. *Nutrition* **30**, 841–846.
43. Chapman CE, Irwin C, Hopper Z, *et al.* (2025) Accuracy of reported energy in food and beverages supplied to hospital patients. *J Hum Nutr Diet* **38**, e13394.
44. FAO/WHO/UN Expert Committee (2003) *Food Energy - Methods of Analysis and Conversion Factors: Report of a Joint FAO/WHO Ad Hoc Expert Committee* [Meeting Held in Rome from 3 to 6 December, 2003]. no. 9789251052129. Rome: FAO/WHO/UN.
45. Food Standards Australia New Zealand (2021) Australian Food Composition Database. https://www.foodstandards.gov.au/science-data/food-composition-databases (accessed 01 May 2023).
46. Urban LE, Lichtenstein AH, Gary CE, *et al.* (2013) The energy content of restaurant foods without stated calorie information. *JAMA Intern Med* **173**, 1292–1299.
47. Roberts SB, Das SK, Suen VMM, *et al.* (2018) Measured energy content of frequently purchased restaurant meals: multi-country cross sectional study. *BMJ (Online)* **363**, k4864.
48. Conway JM, Rhodes DG & Rumpler WV (2004) Commercial portion-controlled foods in research studies: how accurate are label weights? *J Am Diet Assoc* **104**, 1420–1424.
49. Livesey G (1992) The energy values of dietary fibre and sugar alcohols for man. *Nutr Res Rev* **5**, 61–88.
50. Noda K, Nakayama K & Oku T (1994) Serum glucose and insulin levels and erythritol balance after oral administration of erythritol in healthy subjects. *Eur J Clin Nutr* **48**, 286–292.
51. Muñoz-Rojas J, Bernal P, Duque E, *et al.* (2006) Involvement of cyclopropane fatty acids in the response of *Pseudomonas putida* KT2440 to freeze-drying. *Appl Environ Microbiol* **72**, 472–477.
52. Goldberg I & Eschar L (1977) Stability of lactic acid bacteria to freezing as related to their fatty acid composition. *Appl Environ Microbiol* **33**, 489–496.
53. Hua L, WenYing Z, Hua W, *et al.* (2009) Influence of culture pH on freeze-drying viability of Oenococcus oeni and its relationship with fatty acid composition. *Food Bioprod Process* **87**, 56–61.
54. Velly H, Bouix M, Passot S, *et al.* (2015) Cyclopropanation of unsaturated fatty acids and membrane rigidification improve the freeze-drying resistance of Lactococcus lactis subsp. lactis TOMSC161. *Appl Microbiol Biot* **99**, 907–918.