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What's (Not) in Your Supplement? An Energy and Macronutrient Analysis of Commercially Available Carbohydrate Gels

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Carbohydrate (CHO) gels are a staple among endurance athletes. When ingested during competition, CHO gels can improve endurance performance by acting as an external energy substrate, sparing endogenous glycogen, mitigating the risk of hypoglycemia, and engaging the central nervous system via receptors in the mouth and gastrointestinal tract. However, published studies and a growing number of anecdotal reports have raised concerns about possible energy and macronutrient deficiencies in several products. We therefore performed a content analysis on CHO gels from Gu Energy, Honey Stinger, Hüma, Maurten, Näak, Precision Fuel, Science in Sport, and Spring Energy. On average, products contained significantly less energy than stated on the labels ($n = 8$, $p = .047$, large effect) but with no discrepancy in CHO content ($n = 8$, $p = .219$, medium effect). Bland–Altman analyses revealed a systematic bias toward less energy and CHO in measured samples relative to the label-derived nutritional information. Moreover, the Spring Energy product fell outside the 95% limits of agreement for both energy and CHO, containing ~71% less energy (53 vs. 180 kcal) and ~72% less CHO (12.5 vs. 45 g) than stated on the label. A follow-up analysis revealed similar discrepancies in several Spring Energy products from multiple lots. These findings have performance, clinical, and legal implications.

Keywords: endurance, ergogenic aid, exercise

Levine et al. (1924) were the first to describe the ergogenic effects of carbohydrate (CHO) supplementation, observing faster finish times and lower prevalence of hypoglycemia in runners of the 1924 Boston Marathon who consumed confectionery during the race. In the century since this pioneering work, research on CHO ingestion during exercise has proliferated. The search term "carbohydrate AND supplementation" now returns ~30,000 articles on PubMed, including numerous expert statements and position stands that reference precise CHO doses, timings, and formulations (Burke et al., 2011; Jeukendrup, 2014; Kerksick et al., 2017; Rodriguez et al., 2009; Tiller et al., 2019). CHO-rich sports foods have become an established and integral component of endurance performance.

Carbohydrate sports drinks were introduced to the market in the 1960s and 1970s to address the problem of dehydration and energy depletion in team sports players. Energy gels emerged shortly thereafter and have become one of the most popular sports foods among athletes (Baur & Saunders, 2021). Gels are portable, easy to store, and provide CHO in precise quantities that are rapidly absorbed across the intestinal epithelium. CHO gels thus enable athletes to follow predefined fueling strategies and are a convenient CHO source for diabetic patients who need to stabilize blood glucose during bouts of hypoglycemia (Juvenile Diabetes Research Foundation, 2022; Mayo Clinic, 2024).

Given their popularity and broad application, it is vital that CHO gels provide the energy and macronutrient amounts stated in their nutritional information. However, data on various sports foods and supplement brands reveal frequent inconsistencies in nutrient composition. For instance, a cross-sectional study of protein bars, powders, and drinks found considerable energy and macronutrient discrepancies between products and their labels, with protein in particular at approximately half the stated amount (Aly et al., 2023). Another study on whey protein supplements found the energy content was significantly higher and the protein content significantly lower than stated in the nutritional information (Zapata-Muriel et al., 2022). Absent or unenforced regulations on dietary supplements and a general lack of quality control have also been blamed for the variable and unpredictable contents of supplements containing ecdysterone (Ambrosio et al., 2020), fish oils (Albert et al., 2015), vitamin D (LeBlanc et al., 2013), selenium (Veatch et al., 2005), and ephedra (Gurley et al., 2000), among others. Although United States, Canadian, and European regulations allow macro- and micronutrients to be 20% above or below the declared amounts, depending on the nutrient (e.g., Center for Food Safety and Applied Nutrition, 2024), many of the above studies observed values considerably outside the acceptable range.

There are also anecdotal reports in the media that have raised concerns over the nutrient contents of CHO gels and with one brand in particular (Burgess & Ohm, 2024). Not only did athletes complain of fluctuating energy levels when using the product during exercise, but they also noted lower-than-expected satiety with regular consumption (i.e., they could consume twice as many gels as usual) and that the gel's viscosity and taste did not match their expectations based on the purported CHO content. And while personal experiences do not constitute scientific evidence, when interpreted appropriately, anecdotes can offer insights into real-world problems and guide hypothesis generation for scientific research.

Based on the available data, we performed a content analysis on a number of commercially available CHO gels to compare the

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measured energy and macronutrients to the label-derived nutritional information. To our knowledge, this issue has not been addressed in any peer-reviewed analysis, yet, content discrepancies, should they exist, would have profound performance, clinical, and legal implications. We hypothesized that at least one of the eight brands of CHO gel would deviate from the stated energy or macronutrient content by more than 20%.

Methods

Content Analysis

We performed a primary and secondary content analysis on commercially available CHO gels between March and May 2024.

In the primary analysis, CHO gels from eight brands were selected based on their widespread use in competition and perceived popularity among athletes: Gu Energy, Honey Stinger, Hüma, Maurten 100, Näak, Precision Fuel, Science in Sport, and Spring Energy (see Table 1 for product characteristics). Samples were sent to an independent, Food and Drug Administration-accredited facility (Anresco Laboratories) to undergo content analysis via high-pressure liquid chromatography with tandem mass spectrometry. The analysis comprised duplicate measures of the weight of the recovered sample (i.e., all that could be extracted from the package) and its measured energy and macronutrient content (i.e., CHO, protein, and fat).

Results from the primary analysis revealed considerable discrepancies in the measured versus labeled contents of Spring Energy's *Awesome Sauce*. We therefore performed a secondary analysis on three of their products: *Awesome Sauce*, *Hill Aid*, and *Canaberry*. Samples were sent to three independent laboratories (Anresco Laboratories; Normec Abiolab; RL Food Testing Laboratories) to undergo energy, macronutrient, and sodium content analyses. In total, nine different Spring Energy gels from seven lots were tested, and one gel from the same lot was tested in triplicate at two labs. All laboratories were accredited by regional bodies and used similar analytical methods.

Data Analysis

Within-trial reproducibility of the primary lab analysis was calculated using a concordance correlation coefficient based on duplicate measurements, where a concordance correlation coefficient of 1.0 indicated perfect agreement (accuracy and precision). The Shapiro–Wilk test showed a significant departure from normality for all measures. Accordingly, the weight, energy content, and macronutrient content for the primary ($n = 8$) and secondary analysis ($n = 9$) were compared with product labels using a Wilcoxon Signed-Rank test (alpha = .05), with effect size estimates using the rank-biserial correlation ($r < .1$ = no effect, .1 = small effect, .3 = medium effect, .5 = large effect). Absolute and percentage differences were reported as median ± interquartile range. Bland–Altman plots were used to identify systematic differences (i.e., fixed bias) between measured and label-derived values and to detect possible outliers.

Results

Table 1 and Figure 1 show the measured versus label-derived weight, energy, and CHO contents from the primary analysis. Within-trial reproducibility was near perfect, with minimal variation: concordance correlation coefficient was >.999 for sample weight, calories, CHOs, protein, and fat. Figure 2 shows the Bland–Altman plots of agreement between measured and label-derived values.

Weight

The purported weights ranged from 31 to 153 g per serving. Overall, the measured weight was not significantly different from that stated on the product label (difference = –0.5 ± 2.8 g, $p = .109$, $r = .57$). However, the Bland–Altman analysis revealed a systematic bias toward higher values on the labels (Figure 2).

Energy

The purported energy contents ranged from 100 to 360 kcal per serving. Overall, there was a large and significant difference between the measured energy content and values stated on the labels (difference = –6.3 ± 16.8 kcal, $p = .047$, $r = -.75$). The Bland–Altman analysis revealed a systematic bias toward higher values on the product labels (Figure 2). The energy content was within 20% of the label in 7/8 brands (range 0%–12%). However, Spring Energy's *Awesome Sauce* was outside the 95% limits of agreement, containing 71% less energy than stated on the label (53.0 vs. 180.0 kcal; Figure 1 and 2, Table 1).

Macronutrients

The purported CHO content ranged from 22 to 90 g per serving. Overall, the CHO content was not significantly different from values stated on the labels (difference = –0.6 ± 4.4, $p = .219$, $r = -.46$). However, the Bland–Altman analysis revealed a systematic bias toward higher values on the labels (Figure 2). CHO values were within 20% of the label in 7/8 brands (range 0%–15%). However, Spring Energy's *Awesome Sauce* was outside the 95% limits of agreement, containing 72% less CHO than stated on the label (12.5 vs. 45.0 g) (Figure 1 and 2; Table 1). The measured protein and fat content across all brands was low (0–2.0 g), except for Näak's *Apple and Maple Syrup*, which exhibited a measured versus stated protein content of 4.4 g versus 5.0 g, and fat content of 7.9 g versus 8.9 g, respectively.

Secondary Analysis

Three products from Spring Energy—*Awesome Sauce, Hill Aid, and Canaberry*—underwent additional content analyses. The results are shown in Table 2. Overall, there was a large and significant difference between the measured content of Spring Energy products and values stated on the labels, both in terms of energy (difference = –94.5 ± 48.6 kcal, $p = .004$, $r = -.96$) and CHO (difference = –28.9 ± 22.5 g, $p = .004$, $r = -.96$). On an individual basis, all Spring Energy products (9/9) had less energy (range 57%–71%) and CHO (range 43%–72%) than stated. Two samples of Spring Energy's *Awesome Sauce* were analyzed for sodium content. Relative to the purported value of 85 mg, the first sample exhibited a 74% shortfall (22 mg) and the second an 84% shortfall (13.9 mg).

Discussion

Most expert panels at prominent sports science and medicine organizations agree that CHO ingestion during endurance competition has the potential to delay fatigue onset via a range of

Table 1 Primary Analysis: Actual Weight, Energy, and Carbohydrate Content From the Laboratory Analysis Versus Values Declared on the Label

			Weight				Energy				Carbohydrates			
Manufacturer	Product	Lot No.	Label (g)	Actual (g)	Diff (g)	Diff (%)	Label (kcal)	Actual (kcal)	Diff (kcal)	Diff (%)	Label (g)	Actual (g)	Diff (g)	Diff (%)
Gu Energy	Strawberry/Banana	123361_0418	32	31.5	–0.5	–1.7	100	96.5	–3.5	–3.5	23	23.9	0.9	3.9
Honey Stinger	Acai/Pomegranate	24018	31	29.7	–1.3	–4.2	100	99.0	–1.0	–1.0	24	24.7	0.7	2.9
Hüma	Apples/Cinnamon	3081L6	42	41.5	–0.5	–1.2	100	91.0	–9.0	–9.0	22	21.7	–0.3	–1.4
Maurten	100	113286B	40	40.2	0.2	0.5	100	103	3.0	3.0	25	25.0	0.0	0.0
Näak	Apple/Maple Syrup	2613-G20	90	85.6	–4.5	–4.9	200	176.5	–23.5	–12.0	26	22.1	–4.0	–15.0
Precision Fuel	PF90 Original	02-2026-54L	153	153.0	0.0	0.0	360	349.0	–11.0	–3.1	90	85.9	–4.1	–4.6
Science in Sport	Beta Fuel Str/Lime	702002-V2	74	74.1	0.2	0.3	158	158.0	0.0	0.0	40	39.2	–0.8	–2.1
Spring Energy	Awesome Sauce	SSNASO20724A	54	49.9	–4.1	–7.6	180	53.0	–127	–70.6[a]	45	12.5	–32.6	–72.3[a]

Note. Products are listed alphabetically. Actual values are means of duplicate tests.
[a]Outside the 20% allowance.

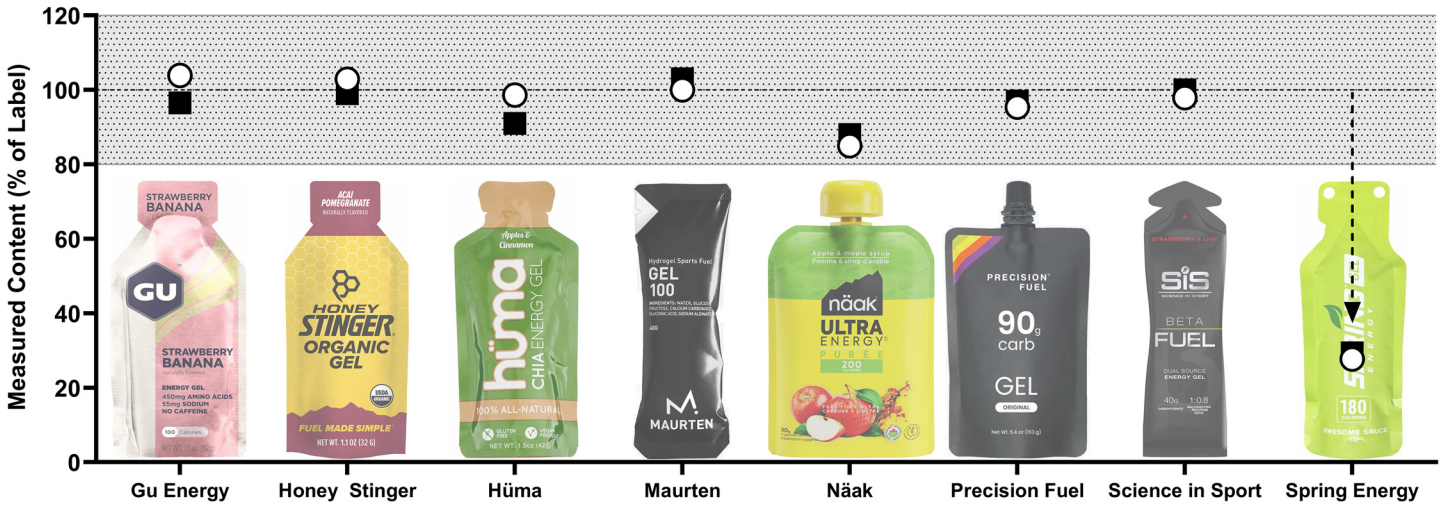

Figure 1 — Actual energy and carbohydrate content from the laboratory analysis as a percentage of values declared on the label. The shaded area represents the 20% upper and lower limits permitted by United States, Canadian, and European governing bodies. ■ = Energy; ○ = Carbohydrates.

mechanisms, including glycogen sparing, maintaining plasma glucose levels, and engaging the central nervous system via receptors in the mouth and gastrointestinal tract (Jeukendrup, 2014; Kerksick et al., 2017; Rodriguez et al., 2009; Tiller et al., 2019). Because CHO gels are portable and convenient, many endurance athletes have come to rely on them to meet their target CHO intakes (Baur & Saunders, 2021). Our analysis revealed a systematic bias toward lower energy and CHO content in a range of popular brands of CHO gel relative to expected values based on their nutritional information. In particular, there were large discrepancies in the energy, CHO, and sodium contents of the Spring Energy *Awesome Sauce* analyzed in this study, with a follow-up analysis revealing similar discrepancies in several of their products from multiple lots. Such shortfalls could have profound implications on health and performance.

In practical terms, an athlete following an hourly fueling strategy of 2 × 54 g servings of Spring Energy's *Awesome Sauce* would expect to ingest 90 g of CHO and 360 kcal. This would meet the recommended CHO intake for competitive marathon running (Burke et al., 2011) and the recommended energy intake for single-stage ultra-marathon (Tiller et al., 2019). However, our analysis indicates that such a fueling strategy could provide just 30 g of CHO and 144 kcal. Such a gross mismatch between the athlete's *perceived* and *actual* intake would likely predispose to early glycogen depletion, hasten fatigue onset, and reduce performance. Our findings likely explain anecdotal reports of low energy and satiety when using the product in early 2024 (Burgess & Ohm, 2024).

Insufficient CHO intake during competition may also increase the athlete's risk of exercise-induced hypoglycemia (plasma glucose < 135 mmol/L). Episodes of hypoglycemia can occur in endurance sports (Bowler et al., 2023) and, if not appropriately managed, can lead to cognitive decline, syncope, and serious health complications. The risks of severe outcomes may be considerably greater at endurance events contested in remote locations (e.g., in the mountains) where the environment can impede prompt medical aid and at ultra-endurance events where contestants may exercise for prolonged periods in relative isolation.

There is also the question of whether low energy and/or CHO intake during training and racing may precipitate poor long-term health. Relative energy deficiency in sport results from a chronic energy imbalance, impairing physiological function in multiple body systems (Dave & Fisher, 2022). Furthermore, low CHO intake during exercise has been shown to increase circulating stress hormones (e.g., cortisol), causing disturbances in several indices of immune function (Gleeson et al., 1998). Thus, by inadvertently underconsuming energy and CHO during exercise, athletes may increase their susceptibility to overtraining-related injury and illness.

In our secondary analysis, two samples of Spring Energy's *Awesome Sauce* were also assessed for sodium content. Being the most abundant electrolyte in sweat, sodium is usually included in energy and hydration supplements due to its essential role in fluid retention, nerve conduction, and facilitating glucose transport against a negative intracellular gradient (Sano et al., 2020). Two servings of *Awesome Sauce* were purported to provide 170 mg of sodium—approximately 50% of the sodium recommendations for prolonged exercise or exercise in hot/humid environments (Kerksick et al., 2018). Our analysis revealed a 74%–84% discrepancy between the content of the lots we tested and their label-derived amounts, such that two servings would provide just 28–44 mg/hr. Adequate sodium intake can mitigate (though not eliminate) the drop in plasma sodium concentration during prolonged exercise thereby reducing the risk of exercise-associated hyponatremia (Veniamakis et al., 2022). The opposite is also true: insufficient sodium intake congruent with inappropriate fluid consumption likely predisposes to hyponatremia, further reiterating the potential harm of a mismatch between perceived and actual intakes.

Consumers are protected by international labeling laws. In the United States, these are defined by Title 21 of the Code of Federal Regulation which comprises two key statutes: (a) the Federal Food, Drug, and Cosmetic Act, enforced by the Food and Drug Administration, concerning labeling and overall safety of food, drugs, and cosmetics and (b) the Federal Trade Commission Act, enforced by the Federal Trade Commission, which prohibits unfair or deceptive practices in commerce, including false advertising. Of the brands we tested, 7/8 complied with these labeling regulations, and 6/8 delivered energy and CHO within 5% of the labeled amounts (Table 1). Näak's Apple and Maple Syrup was the only product besides Spring Energy that was notably below the stated amounts, containing 12% less energy and 15% less CHO than they stated.

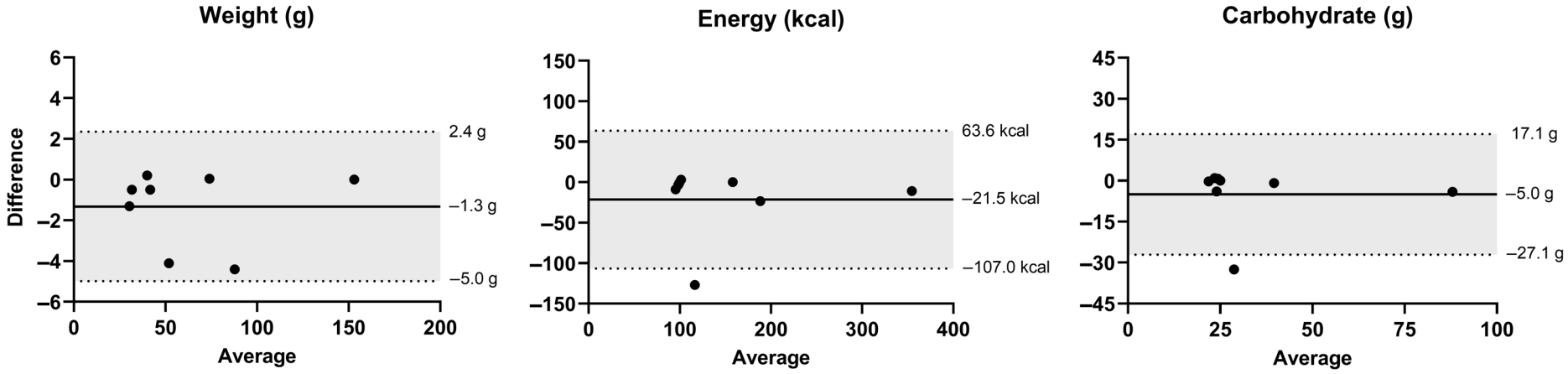

Figure 2 — Bland–Altman assessment of agreement between actual (measured) and label-derived weight, energy, and carbohydrate content of all eight products in the primary analysis. Solid line = mean difference (bias) between the two data sets; dotted lines and shaded area = 95% limits of agreement.

Table 2 Secondary Analysis: Actual Weight, Energy, and CHO Content from the Laboratory Analysis of Spring Energy Products Versus Values Declared on the Label

			Weight				Energy				CHOs			
Manufacturer	Lot No.	Laboratory	Label (g)	Actual (g)	Diff (g)	Diff (%)	Label (kcal)	Actual (kcal)	Diff (kcal)	Diff (%)	Label (g)	Actual (g)	Diff (g)	Diff (%)
Awesome Sauce	SSNASO20724A	Anresco	54	49.9	–4.1	–7.6	180	53.0	–127	–70.6[a]	45	12.5	–32.6	–72.3[a]
Awesome Sauce	SSNASO40424A	Anresco	54	51.3	–2.8	–5.1	180	86.0	–94.0	–52.2[a]	45	14	–31.0	–68.9[a]
Awesome Sauce	SSNASO40424A	Anresco	54	51.5	–2.5	–4.6	180	85.5	–94.5	–52.5[a]	45	13.8	–31.3	–69.4[a]
Awesome Sauce	SSNASO52523A	Anresco	54	51.2	–2.8	–5.3	180	68.0	–112	–62.2[a]	45	16.1	–28.9	–64.2[a]
Awesome Sauce	SSNAS032624A	Normec	54	ND	ND	ND	180	66.4	–113.6	–63.1[a]	45	15.7	–29.3	–65.1[a]
Awesome Sauce	SSNAS040424A	RL Food Testing	54	ND	ND	ND	180	75.1	–104.9	–58.3[a]	45	18.1	–26.9	–59.8[a]
Canaberry	SSNCB041124A	Anresco	46	47.7	1.7	3.7	100	50	–50.0	–50.0[a]	17	9.5	–7.6	–44.4[a]
Canaberry	SSNCB031724R	RL Food Testing	46	ND	ND	ND	100	43.3	–56.7	–56.7[a]	17	9.7	–7.3	–43.2[a]
Hill Aid	SSNHA033124R	RL Food Testing	49	ND	ND	ND	120	48.2	–71.8	–59.8[a]	20	10.3	–9.7	–48.5[a]

Note. Products are listed alphabetically. Only Anresco samples were tested in duplicate. ND = not determined.
[a]Outside the 20% allowance.

This may be partly explained by the product's rigid mouthpiece and cap, which make it more difficult to recover the entire sample from the container. Manifestly, brands can adhere to federal regulations and still fail to provide energy and nutrients in the stated amount. Athletes must be cognizant of this and take practical steps to account for it in their race preparations. If concerned about the content of a product, athletes should consider diarizing their satiety and energy levels during training and racing, monitoring their blood glucose concentrations with a point-of-care handheld device, and assessing their CHO oxidation rates in a lab, should they have the means.

The reason(s) for the large nutrient shortfall in Spring Energy's products was not clear at first. We are confident it was not the result of a smaller quantity of recovered samples in our analysis since the difference was minimal (within 5%). Moreover, we observed shortfalls in all measured characteristics—energy, CHO, and sodium—suggesting an issue with the product's core formulation. Since our analyses, our deductions were confirmed in a statement by Spring Energy in which they acknowledged a problem with the formulation and attributed the issue to (a) the rice cooking method that allowed "too much room for variation in the final product," and (b) the apple sauce supply that had "higher levels of inconsistency than expected," ultimately leading to batches that were "overly diluted." The company has since reformulated its product line (Spring Energy, 2024). Their *Awesome Sauce* now purportedly contains 180 calories, 28 g of CHO, 7 g of fat, and 1 g of protein.

There are several limitations to this analysis. Due to limited funding, we only tested eight brands of CHO gel from over 20 available worldwide, each with different formulations catering to different needs. We selected brands based on their popularity with athletes and coaches. Moreover, for each brand, we tested only one product from each lot (except for Spring Energy, on which we conducted a secondary analysis comprising three products and multiple lots). We urge caution before extrapolating too broadly from the primary analysis.

Readers may also have noted a measurement discrepancy from Table 2, where Spring Energy's *Awesome Sauce* lot numbers SSNASO20724A and SSNASO40424A exhibited similar CHO (12.5 vs. 14.0 g) but markedly different calories (53 vs. 86 kcal, respectively). The laboratory measured 3.2 g of fat in the second sample, even though the product is listed as being fat free (0.0 g). The company makes other products/flavors that contain small amounts of fat (e.g., its *Canaberry Smoothie Gel* contains 3.0 g of fat, presumably from the coconut oil in its ingredients list). Thus, the most likely explanation is the inadvertent contamination of the second *Awesome Sauce* lot. This is not a new problem in sport. Dietary supplement contamination is widespread (Geyer et al., 2008, 2008), attributed to poor manufacturing practices and, in some cases, deliberate product adulteration (Maughan, 2005). Our findings underscore the critical need for athletes to remain vigilant and well-informed about the supplements they consume, carefully evaluating product quality and authenticity.

In conclusion, this is the first published content analysis of commercially available CHO gels. Seven of the eight brands we tested had energy and macronutrient contents within 15% of the labeled amounts, thus conforming to federal regulations. However, three products from one brand were considerably outside the acceptable limits for energy and CHO. The product has since been reformulated, but our data serve as a cautionary tale for athletes to take more ownership of the sports products they consume. We urge product manufacturers to pay close attention to their production values and quality control.

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References

Albert, B.B., Derraik, J.G.B., Cameron-Smith, D., Hofman, P.L., Tumanov, S., Villas-Boas, S. G., Garg, M.L., & Cutfield, W.S. (2015). Fish oil supplements in New Zealand are highly oxidised and do not meet label content of n-3 PUFA. *Scientific Reports, 5*(1), Article 7928. https://doi.org/10.1038/srep07928

Aly, M.O., Ghobashy, S.M., & Aborhyem, S.M. (2023). Authentication of protein, fat, carbohydrates, and total energy in commercialized high protein sports foods with their labeling data. *Scientific Reports, 13*(1), Article 15359. https://doi.org/10.1038/s41598-023-42084-3

Ambrosio, G., Wirth, D., Joseph, J.F., Mazzarino, M., de la Torre, X., Botrè, F., & Parr, M.K. (2020). How reliable is dietary supplement labelling?-Experiences from the analysis of ecdysterone supplements. *Journal of Pharmaceutical and Biomedical Analysis, 177*, Article 112877. https://doi.org/10.1016/j.jpba.2019.112877

Baur, D.A., & Saunders, M.J. (2021). Carbohydrate supplementation: A critical review of recent innovations. *European Journal of Applied Physiology, 121*(1), 23–66. https://doi.org/10.1007/s00421-020-04534-y

Bowler, A.-L.M., Whitfield, J., Marshall, L., Coffey, V.G., Burke, L.M., & Cox, G.R. (2023). The use of continuous glucose monitors in sport: Possible applications and considerations. *International Journal of Sport Nutrition and Exercise Metabolism, 33*(2), 121–132. https://doi.org/10.1123/ijsnem.2022-0139

Burgess, B., & Ohm, J. (2024, June). Investigation: Lab tests confirm spring energy misrepresents carbs and calories, 7 other brands have accurate labels. *iRunFar*. https://www.irunfar.com/spring-energy-awesome-sauce-gel-controversy-lab-results

Burke, L.M., Hawley, J.A., Wong, S.H.S., & Jeukendrup, A.E. (2011). Carbohydrates for training and competition. *Journal of Sports Sciences, 29*, S17–27. https://doi.org/10.1080/02640414.2011.585473

Center for Food Safety and Applied Nutrition. (2024, January 25). Guidance for industry: Food labeling guide. *FDA*. https://www.fda.gov/regulatory-information/search-fda-guidance-documents/guidance-industry-food-labeling-guide

Dave, S.C., & Fisher, M. (2022). Relative energy deficiency in sport (RED-S). *Current Problems in Pediatric and Adolescent Health Care, 52*(8), Article 101242. https://doi.org/10.1016/j.cppeds.2022.101242

Geyer, H., Parr, M.K., Koehler, K., Mareck, U., Schänzer, W., & Thevis, M. (2008). Nutritional supplements cross-contaminated and faked with doping substances. *Journal of Mass Spectrometry, 43*(7), 892–902. https://doi.org/10.1002/jms.1452

Gleeson, M., Blannin, A.K., Walsh, N.P., Bishop, N.C., & Clark, A.M. (1998). Effect of low- and high-carbohydrate diets on the plasma glutamine and circulating leukocyte responses to exercise. *International Journal of Sport Nutrition, 8*(1), 49–59. https://doi.org/10.1123/ijsn.8.1.49

Gurley, B.J., Gardner, S.F., & Hubbard, M.A. (2000). Content versus label claims in ephedra-containing dietary supplements. *American Journal*

of Health-System Pharmacy, 57(10), 963–969. https://doi.org/10.1093/ajhp/57.10.963

Jeukendrup, A. (2014). A step towards personalized sports nutrition: Carbohydrate intake during exercise. *Sports Medicine, 44*(Suppl 1), 25–33. https://doi.org/10.1007/s40279-014-0148-z

Juvenile Diabetes Research Foundation. (2022). *Not all sugars are the same: Using glucose to treat hypoglycemia*. https://jdrf.ca/not-all-sugars-are-the-same-using-glucose-to-treat-hypoglycemia/

Kerksick, C.M., Arent, S., Schoenfeld, B.J., Stout, J.R., Campbell, B., Wilborn, C.D., Taylor, L., Kalman, D., Smith-Ryan, A.E., Kreider, R.B., Willoughby, D., Arciero, P.J., VanDusseldorp, T.A., Ormsbee, M.J., Wildman, R., Greenwood, M., Ziegenfuss, T.N., Aragon, A.A., & Antonio, J. (2017). International society of sports nutrition position stand: Nutrient timing. *Journal of the International Society of Sports Nutrition, 14*(1), Article 33. https://doi.org/10.1186/s12970-017-0189-4

Kerksick, C.M., Wilborn, C.D., Roberts, M.D., Smith-Ryan, A., Kleiner, S.M., Jäger, R., Collins, R., Cooke, M., Davis, J.N., Galvan, E., Greenwood, M., Lowery, L.M., Wildman, R., Antonio, J., & Kreider, R.B. (2018). ISSN exercise & sports nutrition review update: Research & recommendations. *Journal of the International Society of Sports Nutrition, 15*(1), Article 38. https://doi.org/10.1186/s12970-018-0242-y

LeBlanc, E.S., Perrin, N., Johnson, J.D., Ballatore, A., & Hillier, T. (2013). Over-the-counter and compounded vitamin D: Is potency what we expect? *JAMA Internal Medicine, 173*(7), 585–586. https://doi.org/10.1001/jamainternmed.2013.3812

Levine, S.A., Gordon, B., & Derick, C.L. (1924). Some changes in the chemical constituents of the blood following a marathon race: With special reference to the development of hypoglycemia. *Journal of the American Medical Association, 82*(22), 1778–1779. https://doi.org/10.1001/jama.1924.02650480034015

Maughan, R. (2005). Contamination of dietary supplements and positive drug tests in sport. *Journal of Sports Sciences, 23*(9), 883–889. https://doi.org/10.1080/02640410400023258

Mayo Clinic. (2024). *Diabetes and exercise: When to monitor your blood sugar*. https://www.mayoclinic.org/diseases-conditions/diabetes/in-depth/diabetes-and-exercise/art-20045697

Rodriguez, N.R., Di Marco, N.M., & Langley, S. (2009). American college of sports medicine position stand. Nutrition and athletic performance. *Medicine and Science in Sports and Exercise, 41*(3), 709–731. https://doi.org/10.1249/MSS.0b013e31890eb86

Sano, R., Shinozaki, Y., & Ohta, T. (2020). Sodium–glucose cotransporters: Functional properties and pharmaceutical potential. *Journal of Diabetes Investigation, 11*(4), 770–782. https://doi.org/10.1111/jdi.13255

Spring Energy. (2024). Spring energy. *Myspringenergy*. https://myspringenergy.com/pages/product-inconsistencies

Tiller, N.B., Roberts, J.D., Beasley, L., Chapman, S., Pinto, J.M., Smith, L., Wiffin, M., Russell, M., Sparks, S.A., Duckworth, L., O'Hara, J., Sutton, L., Antonio, J., Willoughby, D.S., Tarpey, M.D., Smith-Ryan, A.E., Ormsbee, M.J., Astorino, T.A., Kreider, R.B., … Bannock, L. (2019). International Society of Sports Nutrition position stand: Nutritional considerations for single-stage ultra-marathon training and racing. *Journal of the International Society of Sports Nutrition, 16*(1), Article 50. https://doi.org/10.1186/s12970-019-0312-9

Veatch, A.E., Brockman, J.D., Spate, V.L., Robertson, J.D., & Morris, J.S. (2005). Selenium and nutrition: The accuracy and variability of the selenium content in commercial supplements. *Journal of Radioanalytical and Nuclear Chemistry, 264*(1), 33–38. https://doi.org/10.1007/s10967-005-0671-3

Veniamakis, E., Kaplanis, G., Voulgaris, P., & Nikolaidis, P.T. (2022). Effects of sodium intake on health and performance in endurance and ultra-endurance sports. *International Journal of Environmental Research and Public Health, 19*(6), Article 3651. https://doi.org/10.3390/ijerph19063651

Zapata-Muriel, A., Echeverry, P., Van Dusseldorp, T.A., Kurtz, J., & Monsalves-Alvarez, M. (2022). Measured versus label declared macronutrient and calorie content in Colombian commercially available whey proteins. *Journal of the International Society of Sports Nutrition, 19*(1), 258–266. https://doi.org/10.1080/15502783.2022.2090828

Nontechnical Summary

In 1924, researchers discovered that runners at the Boston Marathon ran considerably quicker when they consumed carbohydrate (CHO)-based confectionary products during the race. In the century since this study, CHO supplements have been extensively researched and highly commercialized, with drinks, gels, and candies marketed to athletes around the world.

Carbohydrates are among the few products in the lucrative world of dietary supplements that are supported by scientific evidence. Eating or drinking CHO during endurance exercise may improve performance by providing the body with energy, sparing the body's internal CHO stores, and helping to maintain blood sugar levels. Of all CHO supplements, gels are among the most popular. These semiliquid substances are usually made of simple sugars. They are portable, easy to store, and contain CHO in premeasured amounts, making it easy for athletes to fuel on the go. What's more, people with diabetes—a medical condition where the body has trouble controlling blood sugar levels—sometimes use CHO gels when their blood sugar gets too low.

However, there is growing concern that various sports foods and supplements may not contain the nutrients they claim, prompted by various studies and an increasing number of athlete testimonials. For instance, research on whey protein bars and powders, fish oils, and vitamin D, among many other supplements reveals considerable shortfalls in the products' measured versus stated amounts—far outside the acceptable range stated by United States, Canadian, and European regulators. With CHO gels, athletes have voiced their concerns about one brand in particular, complaining of fluctuating energy levels when using the product during exercise, noting lower-than-expected feelings of fullness with regular consumption, and an unexpected consistency and taste relative to the ingredient profile. If shortfalls in commercial CHO gels exist, it could have major implications on health and performance.

To provide clarity on this issue, we selected eight brands of CHO gel that we perceived to be among the most popular with athletes and sent them to an accredited laboratory to have their contents analyzed. The brands were Gu Energy, Honey Stinger, Hüma, Maurten 100, Näak, Precision Fuel, Science in Sport, and Spring Energy. The lab used a technique called high-pressure liquid chromatography with tandem mass spectrometry, whereby each gel was separated into its various components (e.g., CHO, proteins, and fats), and the specific number of molecules identified based on their mass. The technique allowed us to accurately determine each gel's total CHO and energy content.

On average, the eight brands of CHO gel weighed the same as expected based on the product label, and there was no overall (average) difference in stated versus actual CHO content. The measured energy content, however, was significantly lower than stated. Of course, looking at the results overall doesn't allow us to identify outliers in the data. When we assessed gels individually, we found that nearly all of the products (7/8) had energy and CHO values within 20% of that stated on the label, thus conforming to United States, Canadian, and European regulations. However, Spring Energy's *Awesome Sauce* gel was a statistical outlier, containing 71% less energy than stated on the label (53.0 vs. 180.0 kcal) and 72% less CHO (12.5 vs. 45.0 g).

Due to the large shortfall in energy and CHO, we performed a follow-up analysis on three Spring Energy products: *Awesome Sauce, Hill Aid, and Canaberry*, totaling nine gels from multiple lots to test if it was an issue isolated to a single batch. We found a similar trend for all products: compared with the labels, the gels contained considerably less energy (range 57%–71%), CHO (range 43%–72%), and sodium (74%–84%).

The implications could be profound. Athletes using these products during exercise would experience a gross mismatch between their *perceived* and *actual* energy and CHO intake. This could predispose them to early fatigue and low blood sugar and compromise their performance. By underconsuming sodium, athletes competing in very long races (e.g., ultramarathon) or in hot and humid conditions may be at greater risk for low blood sodium—a potentially fatal medical condition. Lastly, people with diabetes require precise and consistent information about the CHO and sugar content of their food. The discrepancy we identified could have serious consequences for blood sugar control, and we recommend that individuals avoid products on which they cannot rely.

Spring Energy has since reformulated its product line, stating that *Awesome Sauce* now contains 180 calories, 28 g of CHO, 7 g of fat, and 1 g of protein. However, our data serve as a cautionary tale for athletes. We urge them to remain vigilant, carefully consider the content and quality of their foods and supplements, and generally take more ownership of their sports nutrition. It is also a cue for product manufacturers to pay closer attention to their production values and quality control.