RESEARCH MANUSCRIPT

On the Formation of the Acid–Flavor Profile of Traditional Shchi

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Interdisciplinary study: food chemistry, fermentation microbiology, sensory analysis, food history

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> "Shchi (pronounced 'shtshee') ···proved quite drinkable, although they contained some sour element, perhaps necessary for Russian palates." "···this place was also remarkable for our first tasting the native soup, ЩІ, (pronounced shtshee), which was quite drinkable, though it contained some sour element, which perhaps is necessary for Russian palates." ***Lewis Carroll,* The Russian Journal*, late July 1867 [42]***

Abstract

Two distinct questions commonly conflated in culinary literature are examined: (1) what determines the acid–flavor profile of shchi—a chemical–sensory question; and (2) what features make a dish shchi—a categorical question. The need to distinguish them methodologically is substantiated: the former requires instrumental and sensory experiments, whereas the latter requires testing competing categorization models. A three-level analytical architecture (chemical → sensory → categorical) is proposed, separating chemical state (pH, titratable acidity, buffer capacity, absolute concentrations, and relative acid composition) from sensory profile A_s (intensity, duration, temporal position, and descriptors of character). Acidity sources are classified by the form in which acid is introduced and the time of addition. Cabbage is described as a functional carrier of several functions, but its historical predominance is not treated as evidence of optimality or necessity. A "Shchi Index," ИЩ_rule, is formulated as a preliminary linear feature score; a separate prototype model, S_proto, measures similarity to an empirical center. Both are to be compared with an exemplar model and simple rules, and neither constitutes a definition of cultural membership. The boundary case of *kapuśniak* demonstrates that differently named categories may have identical vectors of structural axes; hence the predictive value and sufficiency of those features, and the effect of explicit labeling, must be tested separately. Nine falsifiable predictions (P1–P9) and a five-experiment program (Experiments 0–4), including randomized relabeling in Experiment 3, are proposed. This work is a research program: no original experiments have been carried out. Its defensible contribution is the separation of chemical, sensory, and categorical levels and the construction of models that generate discriminating tests.

Keywords: shchi, sauerkraut, lactic acid fermentation, organic acids, pH, titratable acidity, buffer capacity, sensory analysis, prototype, umami, green tomatoes, sorrel, culinary classification.

1. Introduction

1.1. Statement of the problem

In popular understanding, shchi are "cabbage soup," while sour shchi are "shchi made with sauerkraut." Culinary reality is broader than either definition: there are shchi without cabbage (sorrel, nettle, ground elder), shchi with fundamentally different levels of acidity (from neutral to sharply sour), fasting and "rich" shchi, day-old and freshly cooked shchi —and bearers of the tradition classify all of these within the same category. This gives rise to two questions that must be distinguished from the outset:

Q1 (chemical–sensory): what forms the acid–flavor profile of shchi?

Q2 (categorical): what features make a dish shchi?

Conflating these questions is the main methodological risk: a person may call a soup shchi not because it has a certain pH or technology, but because they recognize it as a cultural type. A dish may be chemically almost indistinguishable from shchi and yet not be perceived as shchi —and vice versa. Q1 and Q2 therefore require different tools, and the present study pursues them in parallel without reducing one to the other.

1.2. Historical context and its evidentiary weight

The Old Russian form of the word is *shti*, attested in the *Domostroi* (sixteenth century). According to one hypothesis it derives from Old Russian *sъto*, "sustenance"; according to another, it is related to "sorrel" [33].

Dialect meanings are broad: "cooked dish, broth, soup seasoned with cabbage, sorrel, and other greens" [33]. The *Domostroi* mentions shchi as an everyday dish across social estates [34, 35]. Cabbage, which spread in Rus' approximately from the ninth century, became the principal ingredient owing to its yield and storability [35], but the seasonal cycle included substitutes: ground elder and nettle in spring, followed by sorrel and cabbage seedlings [35, 36]. Prolonged slow cooking in a Russian stove was a technological constant [35, 36]; historical sour dressings included cabbage brine, stewed sour apples, and smetana [35].

Birch-bark letters: limited evidence. Novgorod birch-bark letter No. 1159 (late fourteenth to first quarter of the fifteenth century) contains the word "cabbage" next to a formula concerning a witness. The fragment is interpreted as part of a deed of sale, probably concerning a garden plot [41]. This directly documents a reference to cabbage in an economic–legal context, but supplies no evidence of its widespread cultivation, trade in cabbage as food, fermentation, or use in shchi. In the mid-sixteenth century the *Domostroi* records household preservation of cabbage as an economic norm ("salt cabbage in autumn" — wording as quoted in [35]; see [34]).

Literary record. By the early nineteenth century shchi already functioned as a cultural symbol. In Pushkin's *Fragments from Onegin's Journey*: "My ideal now is a housewife, / My wishes are peace, / And a pot of shchi, and I myself the master" [44]. The verse is based on a Russian proverb meaning "I eat simple food, but I am my own master" ; the pot of shchi signifies plain food and personal independence. In the first chapter of Gogol's *Dead Souls*, Chichikov ends his day with "a portion of cold veal, a bottle of sour shchi, and a sound sleep at full pumping speed" [43]; for the expression "a bottle of sour shchi," see §5.4.

Caveat on evidentiary value. Etymology is *consistent with* the hypothesis that the name was historically not rigidly tied to cabbage, but does not prove the structure of the modern category. Lexical history itself contains a counterexample (§5.4): "sour shchi" also historically referred to a sour malt-and-honey beverage [35]. Linguistic membership cannot therefore serve as direct proof of culinary structure. Historical material is used here as compatible context, not as the basis for conclusions. The companion work on borscht [47] adopts the same principle: its historical–cultural survey (etymology, imperial canonization, diasporas) provides context consistent with the model, not proof of the model.

An external perspective. Lewis Carroll, who visited Russia in 1867, recorded that shchi ("shtshee") were "quite drinkable" although they contained a sour element possibly necessary for Russian palates [42]. This quotation has limited evidentiary value: it establishes only that a sour component was perceptible to one foreign observer in the nineteenth century. It does not establish the prevalence, typicality, or constitutive role of acidity.

Summary of historical evidence. To make the evidentiary discipline explicit, each historical fact is paired with what it permits one to suppose and what it does not prove:

Fact	What it suggests	What it does NOT prove
Birch-bark letter No. 1159 (late fourteenth to first quarter of fifteenth century): cabbage mentioned in the probable context of a land sale [41]	Cabbage was recorded in an economic–legal context	Widespread cabbage cultivation or fermentation; its role in diet or shchi
Etymology of *shti* and broad dialect meanings [33]	The name was not historically rigidly tied to cabbage	The structure of the modern dish category; the antiquity of any recipe
Shchi as an everyday dish of all estates in the *Domostroi* [34]	Early normative status of the dish	Composition or acidity of those shchi
Domostroi: "salt cabbage in autumn" (as quoted in [35]; see [34])	Household cabbage preservation as a sixteenth-century economic norm	That sauerkraut was used specifically in shchi; its acid profile
Seasonal substitutions (ground elder, nettle, sorrel, seedlings) [35, 36]	Functional replaceability of the vegetable-body carrier	Sensory equivalence with cabbage

Fact	What it suggests	What it does NOT prove
Slow cooking in a Russian stove as a technological constant [35, 36]	Primacy of cooking technology in dish identity	Necessity of slow cooking (tested with axis T)
Historical sour dressings (brine, stewed apples, smetana) [35]	Long-standing variability in acidity sources	Acidity as a constitutive feature
"Sour shchi" as a beverage (polysemy) [34, 35, 43]	The lexical category is graded and polysemous	Any inference about soups from usage (§5.4)
Carroll's observation (1867) [42]	Sensory salience of a sour component to an external observer	Necessity, intensity, or source of acidity
Pushkin and Gogol: shchi as a cultural symbol [43, 44]	Early categorical stability	Chemical–sensory properties of the dish

1.3. Aim, objectives, and status of the study

Aim —to develop a model of how the acid–flavor profile of shchi is formed and a preliminary model of structural–sensory similarity to the shchi category, distinguishing this from the cultural identification of the dish and deriving testable consequences for competing explanations.

Objectives: (1) systematize evidence on fermentation, organic acids, and sourness perception; (2) decompose the "acid profile" into measurable components; (3) characterize cabbage as a functional carrier and research variable; (4) formulate the structural-similarity model and delimit its scope of applicability; (5) compare prototype, exemplar, rule-based, and cultural–contextual explanations of categorization; (6) propose falsifiable predictions; and (7) develop an experimental program.

Status. This is a theoretical and modeling study. Experimental data on shchi themselves are absent from the literature, and no original experiment has been performed. Three levels of claims are distinguished and marked: **[E]** —established by cited evidence (Russian [Д]); **[T]** —transfer from adjacent domains to shchi (plausible, untested; Russian [П]); **[H]** —author's own hypothesis (Russian [Г]).

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2. What Is Known

2.1. Cabbage fermentation

[E] Spontaneous cabbage fermentation has traditionally been described as a succession from early heterofermentative bacteria to later acid-tolerant lactic acid bacteria. Modern culture-based and molecular research, however, reveals a more complex and variable community that includes several species of *Leuconostoc*, *Weissella*, *Lactiplantibacillus*, and other genera; its dynamics depend on salt, temperature, raw material, and process scale [4, 5, 10]. The two-phase scheme should be regarded as a teaching approximation rather than a complete description of succession. Sauerkraut contains organic acids including lactic acid (a structural, "indispensable" component [7]), as well as citric and acetic acids [2]. The bacterial community plays a leading role in producing acids and volatile compounds [1]; salting concentration affects the microbiome and metabolite profile [2, 5]; fermentation conditions can be optimized, even for salt-free fermentation [37].

[E] Important recent caveat: the linear two-phase scheme is a simplification. A 2026 paper tracks complex temporal changes in microbial communities and metabolites in a single industrial fermentation regime (18 °C; 25 m^3 vessel), but does not itself compare temperatures or scales [10]. Together with studies of salt, raw material, and starter cultures [2–6], this shows that "fermentation stage" should be characterized by measured process parameters, not just the presumed name of a microbial phase.

[E] Flavor and aroma in fermented cabbage reflect not only acids but glucosinolate degradation products and sulfur-containing volatile compounds [9]; sauerkraut retains appreciable amounts of vitamin C [9].

[T] Transfer to Russian practice: most of the data were obtained on northeastern Chinese cabbage fermentations. Russian cultivars, salting practices, and temperatures may produce different profiles. Any conclusions about "Russian sauerkraut" here are extrapolations requiring verification.

2.2. pH, titratable acidity, and perceived sourness are three different quantities

[E] pH reflects hydrogen-ion activity, whereas titratable acidity (TA) expresses an acid reserve operationally defined as the quantity of alkali needed to titrate a sample to a specified endpoint. The two are not interchangeable and do not uniquely determine sensory sourness [50, 51]. In particular fruit and vegetable systems, sensory ratings are associated with TA and the sugar-to-acid ratio [16, 17], but generalizing these relationships to shchi is a hypothesis, not an established universal law. Different acids at equal pH may differ in perceived intensity and astringency [50]. Sour-taste physiology involves pH-dependent ion mechanisms in taste cells [15]; the trigeminal contribution of acetic acid adds another perceptual pathway [18]. Reference [14] addresses the classification of beer mouthfeel and is not used as primary evidence linking pH, TA, and sourness.

[E → T] A third parameter is important in the shchi matrix: **buffer capacity**, the resistance of a system to changes in pH. Shchi contain proteins, amino acids, phosphates, organic acids, salts, starch, and fat, forming a buffering matrix. The same acid dose added to two shchi matrices of different buffer capacity produces different pH shifts. Hence buffer capacity must be measured experimentally (the application of general solution chemistry to shchi is level [T]).

Buffer-capacity measurement protocol. Because practical questions may involve either additional acidification or neutralization of an acidic matrix, these directions must be measured separately. A standardized homogenized sample is titrated on two branches: with strong acid to assess resistance to further decreases in pH, and with strong base (e.g., NaOH of known concentration) to assess resistance to increases in pH and relation to TA. A titration curve is obtained for each branch at controlled temperature. Local buffer capacity is estimated as $\beta \approx |\Delta n| / (V \cdot |\Delta pH|)$, where Δn is the amount of added strong titrant and V is sample volume. Sample preparation must be identical across all specimens because soup heterogeneity (proteins, starch, fat, organic acids) itself contributes substantial variation.

Buffer-sensitivity coefficient. The acid and base branches are not interchangeable: NaOH titration alone does not directly establish resistance to further acidification. For practical comparisons, separate local estimates **β_acid** and **β_base** are therefore recorded over prespecified pH intervals. They quantify the amount of strong acid or base needed for a unit pH shift in the soup matrix. The pH ranges and titration step must be fixed before the experimental series.

2.3. Taste interactions

[E] Salt interacts with sour and bitter tastes [13]. Sweetness, fat content, and perceived "creaminess" also interact; effect sizes depend on food matrix and taster phenotype [19, 23]. Source [20] examines links between habitual diet and chemosensory capacities; it is not cited here as direct evidence for a sourness–fat interaction. An overall framework for taste interactions is provided in [21]. Sour and umami tastes can modulate one another's intensity; the direction depends on concentrations and matrix [49]. *("Umami" denotes a basic taste linked primarily to glutamate and enhanced by certain nucleotides; such substances occur in meat, mushrooms, ripe tomatoes, and fermented foods.)*

[H] In shchi, umami-bearing components (tomato, mushrooms, meat) may change the overall flavor balance and relative salience of sourness. The direction and magnitude of this effect in shchi remain unknown and must be tested.

2.4. Tomatoes

[E] The major organic acids of tomatoes are citric and malic. Their ratio and total levels depend substantially on cultivar and ripeness (unripe fruits have greater acidity and lower levels of sugars and glutamate) [25, 26,

27]. The chemical profile extends beyond those "major acids" and includes, among others, ascorbic acid and free amino acids such as glutamate, the principal contributor to umami in ripe fruit [26, 27]. Tomato sensory qualities can be predicted from metabolite profiles [28]. Particularly relevant here is research showing that fermentation of **unripe tomatoes** by yeasts and lactic acid bacteria produces an organic-acid profile (citric, acetic, malic, lactic) and umami-associated amino acids [24].

2.5. Sorrel and oxalates

[E] In one study of two cultivars of *Rumex acetosa*, total leaf oxalates ranged from 273 to 954 mg per 100 g fresh weight [38]. This range relates to particular cultivars and leaf sizes and is not a universal constant for sorrel. Cooked products retained sour flavor after dilution. The authors proposed that calcium from smetana might convert some soluble oxalates to an insoluble form, but the soup recipe also changed dilution, heating, and composition, so the study did not isolate a specific smetana effect [38]. Sources [22, 38] do not justify attributing all of sorrel' s perceived astringency to oxalates. Blanching and discarding the water may reduce soluble oxalate consumption, whereas cooking sorrel directly in soup does not guarantee such a reduction because compounds transferred to the liquid remain in the dish. The quantitative effect for sorrel shchi requires a separate experiment.

[T] Sorrel is an experimentally valuable case: "sourness" is not equivalent to the presence of ordinary food acids. Sour sensation, astringency, mineral interactions, and green aroma act together; two systems at the same pH may be sensorially very different. This directly supports the central research hypothesis (§7, P1–P2).

2.6. History and cultural context

[T] The source corpus consulted for this manuscript did not yield specialized experimental studies of shchi as a separate food-science object. Because no systematic search with prespecified databases, queries, languages, and inclusion criteria was performed, this observation does not prove that such studies do not exist and is not used to claim strong priority. Before publication of the empirical part of the work, the search must be registered and reproducibly described. Historical and cultural sources include an etymological dictionary [33], the *Domostroi* [34], popular-scientific and authored histories of cuisine [35, 36, 39], and studies of food practices [31, 32]. Related soups (*kapuśniak*, kapusnyak, *kapustnica*, *Sauerkrautsuppe*) are documented in the consulted corpus mainly by culinary sources [40]; historical statements derived from them are illustrative, not evidentiary.

Caveat on historical causality. Claims such as "sour dressings replaced expensive salt" [35] should be weakened: high salt prices in particular historical and social settings *may* have increased the importance of alternative flavoring methods. Salt-price history is a separate question, and no causal inference is made here. What is established [E] is only that sour products fulfilled both flavoring and preservation functions [11].

Nutritional context. Unpasteurized sauerkraut may contain viable lactic acid bacteria [11] and retains appreciable amounts of vitamin C [9]. The presence of live microorganisms alone is not evidence of a proven probiotic effect by specific strains. For sorrel shchi, blanching and discarding the water—which may reduce soluble oxalates—must be distinguished from boiling sorrel in the soup itself, where oxalates remain in the consumed liquid [30, 38]. These observations are provided for reference and are not part of the model.

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3. Theoretical Framework: Three Levels of the System

It is proposed to distinguish three connected but nonidentical systems:

```
CHEMICAL LEVEL                  SENSORY LEVEL
 ↪  CATEGORICAL LEVEL
molecules, pH, TA,        →      perceived sourness,           →
 ↪  “shchi / not shchi / to what degree shchi”
buffer capacity,                 sourness character, balance
 ↪  (cultural recognition)
acid profile
```

Each arrow represents a lossy mapping, not an identity. Consequently:

- equal pH or TA does not guarantee the same sensory profile (acid composition and matrix effects; §§2.2–2.3);
- equal sensory profiles do not guarantee equal categorization (cultural prototype; §5);
- therefore “acidity of shchi” and “shchi-ness” are separate subjects, connected empirically rather than by definition.

3.1. Decomposition of the acid profile

The term “acid profile” is divided into two objects so that chemical and sensory levels are not conflated.

Chemical description: C_abs = (c_lac, c_ace, c_cit, c_mal, c_oxa, ⋯), with coordinates representing measured absolute concentrations of lactic, acetic, citric, malic, oxalic, and other detected acids. The summed measured acid concentration **C_total** and compositional profile **C_rel = C_abs / C_total** are also recorded. This distinction is necessary: relative composition conveys no information about total acid load.

Sensory profile: A_s = (I, D, P, R), where:

- **I** —perceived sourness intensity;
- **D** —duration of sour sensation, including aftertaste;
- **P** —time of peak sensation and its temporal course;
- **R** —multidimensional sourness character: softness, sharpness, astringency, fruitiness, and milkiness are rated on separate scales.

Each component is tied to a prespecified measurement procedure:

Component	Measurement method
C_abs, C_total, C_rel —concentrations, total, and relative acid composition	HPLC for nonvolatile organic acids; GC–MS is applied separately to volatile compounds, not as an interchangeable measure of acid composition
I —intensity	One calibrated 0–10 scale with fixed reference samples; the general Labeled Magnitude Scale (gLMS) is not mixed with this scale in the main series
D —duration	Time–intensity analysis: area under the post-swallowing curve and time to half-maximum decay
P —temporal position	Time to the peak of I(t) and prespecified temporal intervals; temporal dominance of sensations (TDS) may be used only as a separate exploratory dominance method
R —character	Each agreed descriptor rated separately on a 0–10 scale; a single nominal choice is not used for principal component analysis (PCA) or distance calculation

Comparison metrics. Absolute concentrations C_abs and C_total are analyzed in their original units (with a suitable transformation if needed). Only the relative profile C_rel is compared using Aitchison dis-

tance—the Euclidean distance between centered-log-ratio (clr) transformed profiles. Zero and nondetected concentrations must be handled according to a prespecified detection-limit-based procedure; without such a procedure clr cannot be calculated. A compositional metric does not replace analysis of absolute concentrations. Sensory distance is defined separately:

$$d_s(x, y) = \Sigma_j\, w_j \cdot d_j(x_j, y_j),\ j \in \{I, D, P, R\},$$

where component distances are normalized by prespecified reference ranges, and $w_j = 0.25$ before calibration. For R, Euclidean distance is calculated from standardized descriptor ratings; Mahalanobis distance may be used only with an adequate sample and a reliably estimated covariance matrix. The weights of d_s are not automatically carried over to the Shchi Index or the taxonomic metric in §5.5: these address different questions.

The central hypothesis of the decomposition is:

> ***[H]*** *Two servings of shchi may have the same intensity I despite different C_abs/C_rel and different sensory profiles (D, P, R). Culinary descriptions such as "short," "long," or "integrated" sourness are treated as shorthand for individual measurable features, not as an independent calculated "depth" index.*

3.2. Two independent scales instead of one

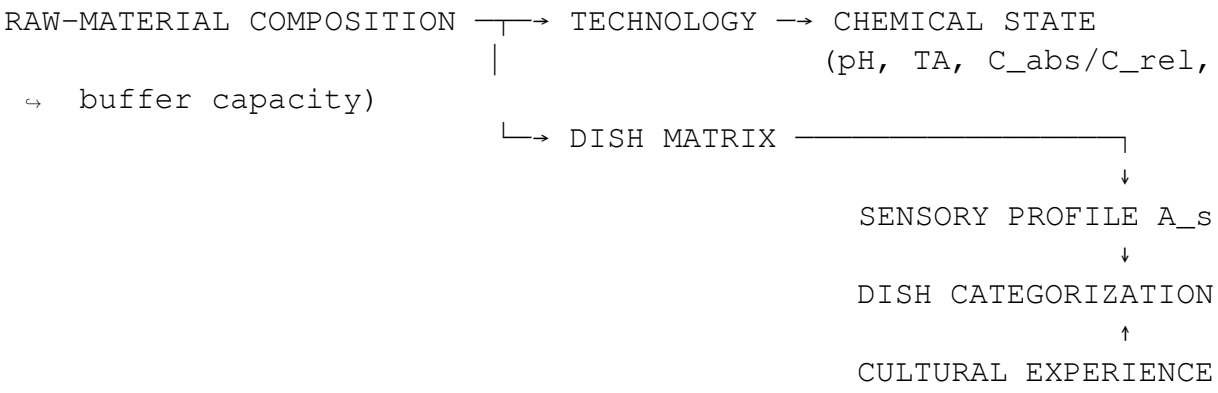
Rather than a single "score ↔ pH" table, which would present a desired relation as a measured one, two independent measurement systems are introduced. Their relationship is an experimental question, not an assumption:

Chemical axis	Sensory axis
pH	Sourness intensity I (0–10)
Titratable acidity	Sourness character (R)
Buffer capacity	Temporal profile (D, P)
Absolute concentrations and relative acid profiles (C_abs, C_rel)	Balance, acceptability
Sugars / salt	Identification ("resembles shchi")

Gastronomic categories (neutral / slight sourness / classically sour / markedly sour) are retained solely as **sensory** categories, without assigning pH intervals before calibration.

3.3. Causal scheme and confounding variables

An explicit causal scheme is specified so that experimental contrasts (§8) may be interpreted causally rather than merely associationally:



Serving temperature, visual information, presentation order, fatigue, and individual perceptual differences are potential sources of systematic bias or effect modifiers; not every one is a confounder in the strict causal sense. Fat content, salinity, and buffer capacity may form part of the matrix' s causal mechanism

and cannot automatically be “adjusted away” without specifying the causal estimand. Section 8 provides randomization, standardization, and stratified analyses as appropriate.

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4. Acid Profile of Shchi

4.1. Classification of acidity sources: form of introduction × time of addition

Dividing sources into “fermentative/nonfermentative” conflates the biochemical origin of an acid with the manner in which it is delivered to the dish. Two independent characteristics are therefore used: **form of introduction** (fermented food matrix / naturally sour unfermented raw material / isolated acid or standardized acidifier) and **time of addition**.

Source	Form of introduction	Time of addition	Expected C_abs/C_rel	Hypothesis concerning R
Sauerkraut	Fermented food matrix	Before cooking (ingredient)	Lactic + citric + acetic [2, 7]	Soft, integrated
Cabbage brine	Fermented food matrix	Before / after cooking	Lactic (+ acetic)	Concentrated, “long”
Fermented green tomatoes	Fermented food matrix	Before cooking	Lactic + citric + malic + acetic [24]	Complex, with umami background
Fermented mushrooms	Fermented food matrix	Before cooking	Lactic	Mushroom character, umami background
Kvass	Fermented food matrix	Before cooking	Lactic + acetic	Bready
Smetana	Fermented food matrix	After cooking (serving)	Lactic	Milky, “rounded” [31]
Fresh tomatoes	Naturally sour unfermented raw material	During cooking	Citric + malic [25–27]	Fresh, fruity
Fresh green tomatoes	Naturally sour unfermented raw material	During cooking	Citric + malic; low sugars [25]	Harsh, herbaceous
Sorrel	Naturally sour unfermented raw material	During cooking	Oxalic (+ malic) [38]	Sharp, astringent [22]
Sour apples (stewed)	Naturally sour unfermented raw material	During cooking	Malic	Soft, fruity [35]
Commercial pickling brine	Standardized acidifier in a food matrix	Before / after	Acetic and other constituents according to actual composition	Sharp, short
Vinegar	Standardized acidifier of fermentative origin	After cooking	Predominantly acetic; other constituents depend on vinegar type	Sharp, volatile

Sensory descriptions in the final column are working hypotheses for evaluation by a sensory panel; they are not deduced directly from chemical composition.

The classification gives rise to a working distinction **[T]**: fermented food matrices can deliver several acids, volatile compounds, amino acids, salts, and sugars [1, 8, 9], whereas an isolated food acid offers a

narrower, more controllable chemical stimulus. Vinegar and commercial marinades are not "one pure acid" and are analyzed according to their actual composition. The hypothesis that an isolated acid can reproduce I but not the full A_s profile of a fermented product is tested in Experiment 2. Any remaining difference is not attributed to a particular unreconstructed component without an additional contrast.

4.2. Cabbage as a functional carrier and independent variable

Cabbage serves several functions simultaneously: vegetable bulk/body, postfermentation acidity, texture, and an aromatic layer. This explains its historical dominance but does not establish optimality or logical necessity. Cabbage state is a genuine experimental variable **[T]**:

State	Fermentation	Sensory reference	Note
Fresh	None	Neutral base	Dense texture; "glassy" if undercooked
Young fermented	Early stage; potentially higher *Leuconostoc/Weissella* proportion [4, 10]	Slight sourness, bright aroma	Microbial composition is measured, not inferred from age
Mature fermented	Later stage; acid-tolerant LAB often increase [4, 5, 10]	Marked acidity, characteristic shchi aroma [9]	No linear two-phase sequence is assumed
Overfermented	Prolonged	High acidity, possibly harsh	Risk of excessive souring
Cabbage seedlings (historical)	None	Green profile	Seasonal variant [35]

Additional variable parameters include salt dose during salting [2, 5, 37], cutting size, cultivar, and washing before addition (which directly reduces the incoming acid load; cabbage in kapusnyak is deliberately not washed [40]).

Caveat. Specific acid ranges for these states (around 1–2% lactic acid and pH approximately 3.3–3.7 in mature sauerkraut) are extrapolated from sauerkraut research [2, 5, 37] and require direct measurements for traditional Russian sauerkraut preparations.

4.3. Tomatoes: a multifunctional module and hybrid case

[E → T] Tomatoes are **among the most clearly** multifunctional shchi ingredients, though not the only ones: sauerkraut is likewise multifunctional. Tomatoes operate on three axes: acidity (citric and malic acids [25–27]), umami (glutamate [26, 27]), and body (pectins and sugars).

Green tomatoes are the central experimental case of the study. The same raw ingredient can be compared fresh and fermented: fresh green tomato has its native plant acidity, while fermented green tomato combines native constituents with substances formed during fermentation [24, 25]. This paired contrast estimates the combined effect of fermenting the same raw ingredient, although it does not isolate acid changes from every other change in the product. Sauerkraut is included solely as an external comparator: replacing tomato with cabbage also changes the raw material and does not isolate the "pathway by which acidity arose."

4.4. Technological regulators

[T] Factors that change the dish profile and/or its matrix:

- **Slow simmering versus vigorous boiling:** traditional Russian-stove technology [35, 36]; gentle simmering integrates flavors differently from vigorous boiling.

- **Sorrel processing:** blanching and discarding the water may reduce soluble oxalate intake; cooking sorrel directly in soup changes texture and distribution of compounds but does not guarantee oxalate removal [30, 38].
- **Broth fat content:** a matrix modulator of perceived sourness (§2.3).
- **Time of sour-component addition** (classification axis §4.1): early addition yields integrated flavor; late addition yields more foregrounded sourness.
- **Flour slurry** (historical rye-flour dressing [36]): a starch-based body regulator, displaced by potatoes while retaining its function.
- **Smetana at serving:** a combined matrix regulator changing portion volume, fat and protein composition, buffer capacity, pH, TA, and perceived sourness; calcium in sorrel shchi may lower the soluble fraction of oxalates [38]. A direct prediction of the model is given in P4.
- **Serving temperature:** a critical sensory variable. Hot and warm shchi may be perceived differently; experiments use a prespecified safe, tolerable temperature range determined in the pilot.
- **Resting (day-old shchi): [H]** Holding is hypothesized to change the profile through diffusion and equalization of the acid–salt background. The claim that sourness "rounds out" is a hypothesis tested by Experiment 4 (0 / 6 / 24 / 48 h, with pH, TA, and sensory measurements).

Accompaniments (serving layer). Traditional accompaniments include dark rye bread (sometimes rubbed with garlic or served with salo), smetana, and fresh herbs. The historical pairing with porridge is already recorded in the *Domostroi* ("shchi, rye porridge" on fasting days [34]); the phrase "shchi and porridge" as a fixed expression is attested in later tradition [35]. As in the companion borscht study [47, §4.4], this layer is treated as an **external cultural modifier**: it affects perception and the dish's cultural status but does not enter the structural axes of the Shchi Index. As with borscht, the functional logic of these accompaniments is that starchy bread and porridge provide a neutral counterpoint to acidity, while salo and garlic contribute fatty and aromatic accents. Smetana has a dual function: both serving accompaniment and final regulator of perceived sourness (see above and P4).

4.5. Control of perceived sourness: four mechanisms

Four means of modifying final sourness are distinguished. Conflating them is the main source of culinary error **[T/H]**:

Mechanism	What happens	Techniques	Change in acid reserve / pH
Dilution + matrix change	Greater volume, lower acid concentrations, increased viscosity and starchiness	Broth, potato, fresh cabbage; washing sauerkraut	Yes, moderate
Matrix modulation	Perception changes with composition and matrix buffering	Smetana, fatty broth, sweetness from carrot and onion	Possible; measured
Chemical neutralization	Shift in acid–base equilibrium, CO_2 release, salt formation, changes to buffer system and aroma	Pinch of baking soda (folk method)	Yes, substantial
Sensory compensation	Redistribution of relative taste salience without necessarily neutralizing acid	Greater umami (tomato, mushrooms), salt, aromatic ingredients	Acid reserve usually retained; total composition changes

A practical hypothesis is to use reversible matrix changes first when acidity is excessive, followed by dilution. Baking soda profoundly alters acid–base equilibrium and aroma. When sourness is insufficient,

brine and vinegar are not considered interchangeable until C_abs/C_rel and A_s have been compared experimentally. Potatoes are not “acid absorbers”: they change volume and matrix but do not themselves neutralize acid.

Status caveat. The four mechanisms are analytical categories, not mutually exclusive strategies. They can operate together (masking and compensation when adding smetana to tomato shchi; dilution and neutralization when adding both broth and baking soda). They may also be described along two axes—chemical versus sensory action and reversibility—but for this study a one-dimensional typology suffices, provided its nonexclusive nature is explicitly acknowledged.

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5. The Shchi Prototype and Categorical Membership

5.1. Why not “necessary features”

Acidity cannot simultaneously be a necessary constitutive feature and an optional axis. In the present model it is a testable graded feature:

> ***[H]*** *Acidity may be a strong prototypical feature of shchi without being a necessary condition for classification. The supposition that sour shchi lie closer to the empirical category center than fresh shchi is tested in Experiment 3, not adopted by definition.*

Likewise, cabbage combines several functions (body, postfermentation acidity, texture, and storability), consistent with its historical dominance, but neither proving its optimality nor making it logically necessary (green and spring shchi [35, 36]).

5.2. Shchi Index (ИЩ) and the competing prototype model

The **Shchi Index (ИЩ)** is introduced (the name reverses the letters of the Russian word *щи*; it is a mnemonic, not a component of the model). Scientifically it is initially defined as a **conceptual linear feature score** along five axes, each ranging from 0 to 1:

$$\text{ИЩ_rule} = w_1 \cdot O + w_2 \cdot V + w_3 \cdot K + w_4 \cdot T + w_5 \cdot N, \text{ with } w_i \geq 0 \text{ and } \Sigma w_i = 1.$$

This formula specifies a monotonic additive rule: increasing an axis with a positive weight always increases the score, and its implicit maximum is at (1, 1, 1, 1, 1). Thus it is **not by itself a distance-to-prototype measure**, and cannot penalize both deficiency and excess relative to a typical feature level. The actual prototype model is specified separately:

$$S_proto(x) = \exp[-d_W(x, \mu)],$$

where μ is an empirically estimated category center and d_W a prespecified weighted distance. The form of distance, possible intermediate optima, and nonlinearities are selected using training data alone and evaluated on independent recipes. ИЩ_rule remains a competing rule-based model rather than being relabeled as a prototype model after the fact.

- **O** —liquid soup form, distinguished from richness of stock;
- **V** —vegetable bulk/body (cabbage or a functional substitute);
- **K** —salience of an acidic component of any origin; its weight is data-determined;
- **T** —degree of technological integration during cooking. Serving with smetana is excluded: it is a separate postcooking matrix intervention;
- **N** —intensity of richness or stock depth, whether from meat or lean sources.

Scale operationalization. Before calibration, each axis is rated on a continuous 0–1 scale with three explicit anchors, 0 / 0.5 / 1, aligned with the companion borscht model [47]:

- O: 0 —the dish lacks a liquid soup form; 0.5 —borderline thick or heterogeneous soup form; 1 —a distinct liquid soup base regardless of richness;

- V: 0 —no vegetable mass; 0.5 —a single vegetable ingredient; 1 —substantial vegetable body (cabbage or a full-proportion functional substitute);
- K: 0 —no acidic component; 0.5 —background acidity; 1 —pronounced sourness;
- T: 0 —components assembled without integrative heat treatment; 0.5 —simple cooking together; 1 — prolonged slow cooking or staged dressing technology that integrates components;
- N: 0 —neutral base without richness; 0.5 —moderate richness from any source; 1 —pronounced richness or stock depth from any source.

Intermediate values are permitted. Anchors are calibration points, not discrete categories. Interrater reliability of every axis is assessed before its use as a predictor.

Status and scope. Weights w_i, center μ, axis independence, and even the selected axes **are not established**. Both models generate predictions; their numerical calibration is the purpose of Experiment 3. Parameters are learned on training data, not assigned by experts. No binary threshold ("score > x → shchi") is introduced: structural similarity is treated as continuous and binary cultural membership is measured separately. Neither linear scoring nor prototype similarity provides an exhaustive definition of the category; the mapping from the five axes to a cultural name may be nonunique.

Competing models. Good prediction from the Shchi Index alone does not prove that participants psychologically use a prototype. Experiment 3 must therefore compare at least three model classes on independent data: (a) a prototype model with one empirical center; (b) an exemplar model comparing new samples with several familiar varieties; and (c) a simple feature/rule model. Family resemblance without a unique center remains possible. The prototype interpretation gains support only if that model reliably outperforms its competitors beyond training data, rather than merely fitting graded judgments [52, 53].

Relation to the companion study' s category framework. Shchi may also be described using Wittgenstein' s "family resemblance" [45]—a category without a single necessary feature, connected by overlapping similarities—but the two frameworks are not synonymous. Rosch' s prototype model [46] presumes a central exemplar with graded membership around it; family resemblance permits overlapping features without a unique center. Here ИЩ_rule is a testable rule model and S_proto a distinct testable prototype model; neither is assumed to describe the category conclusively. Unlike the borscht model [47], shchi initially lack a pigment axis, but that omission too must be tested. Acidity is provisionally optional, but its actual weight remains unknown. This yields a contrastive empirical prediction without prejudging feature importance.

A culinary prototype among prototypes. Prototype organization has been shown in various fields, including colors, animals, and artifacts [46]. Culinary categories differ in two respects: the stimulus is multimodal (taste, smell, color, texture, and temperature enter a common similarity judgment), and the center is culturally conditioned by tradition and may shift between traditions. The latter is itself a testable prediction (Experiment 3, §8).

5.3. Boundary and related cases

Related soups are comparative material demarcating category boundaries—not evidence for the model, which would be circular (define shchi structurally, find similar dishes, then declare that confirmation):

Dish	Why it resembles shchi	Why it may not be shchi
Kapuśniak / kapusnyak [40]	Sauerkraut, brine, and soup structure	Different cultural category and ingredients (smoked meats, millet, beans)
Kapustnica, *Sauerkrautsuppe* [40]	The same sour-cabbage base	Different preparation and flavor framework

Dish	Why it resembles shchi	Why it may not be shchi
Borscht	Vegetable body, broth, sour dressing	Candidate sweetness and earthiness axes of root vegetables (S_1 and S_2 in [47], absent from the shchi model); separate pigment function (betalains, axis Ц[1] [47]); acidity is a potentially strong but not established necessary predictor in borscht [47], while in shchi it is provisionally optional with an uncalibrated weight
Rassolnik	Acid, vegetables, broth	Cucumber-and-grain structure; different V
Solyanka	Acid and rich base	Different compositional category
Vegetable soup	Vegetables and liquid	Lacks characteristic shchi structure (T, V)

Whether a soup can fall equally within the shchi and borscht prototypes (a beet-and-cabbage midpoint) is an open empirical question for comparison of the two models [47].

The boundary case of *kapuśniak*. In the illustrative matrix of Appendix B, classic sour shchi and *kapuśniak* receive the same vector (1, 1, 1, 1, 1), although the table above treats them as different cultural categories. These values are not data and therefore do not empirically refute the Shchi Index. But equality reveals a formal limitation: if two dishes cannot be distinguished using O, V, K, T, and N, no choice of linear index weights can distinguish them. At least three explanations are possible: a cultural label influences identification; tasters use sensory features absent from the five axes; or coarse expert annotation has concealed differences on those axes. Experiment 3 distinguishes these possibilities. Until then the Shchi Index cannot be regarded as a sufficient model of cultural identification.

5.4. Lexical boundary: “sour shchi” as a beverage

Historical polysemy is a counterexample to a direct etymological argument: “sour shchi” also denoted a special sour malt-and-honey beverage [35]. The usage appears in Gogol, whose Chichikov ends the day with “a bottle of sour shchi” [43]—beverages come in bottles; soup is not served that way. Hence historically the word “shchi” did not even guarantee membership in the class of soups. Polysemy limits the force of §1.2 but supports neither the prototype nor the rule-based category model in itself. The narrower methodological conclusion is that lexical analysis cannot substitute for presenting samples and measuring responses from bearers of the tradition. Sample recognition may itself depend not only on physical structure but also on labeling and cultural context; these contributions are to be measured separately in Experiment 3.

5.5. Formal type code

For compact notation a **type code ЩЦ = (O, V, K, T, N)** is introduced, mirroring the borscht code Б = (Ц, К, Б, Т, С) [47] and okroshka code Ок = (О, Х, Н, П, К) [48]. The letters refer to the functional domains of the Shchi Index, but code values are nominal types, not ordered scores. The code asks “how is a feature realized?”; the index asks “to what degree is its function realized?”

Coordinate categories (preliminary; the final typology will be refined from Experiments 0 and 3):

- **O (liquid base):** O1 —water; O2 —weak stock; O3 —rich broth.
- **V (vegetable body):** V0 —absent; V1 —sauerkraut; V2 —fresh cabbage; V3 —greens (sorrel, nettle, ground elder); V4 —mixed or other.
- **K (acid source):** K0 —no pronounced source; K1 —sauerkraut; K2 —brine; K3 —sorrel; K4 —vinegar or isolated acid; K5 —kvass; K6 —tomato/apple; K7 —mixed or other source.

- **T (technology):** T1 —slow cooking (day-old shchi); T2 —simple boiling; T3 —dressed-soup structure (sequential addition and integrative heat treatment); T4 —assembly.
- **N (richness):** N1 —meat stock richness; N2 —mushroom or other lean equivalent (umami); N3 —flour slurry; N4 —no richness (“thin” shchi).

Examples: classic day-old shchi (O3, V1, K1, T1, N1); green shchi with broth (O3, V3, K3, T2, N1); fasting shchi made with water and flour slurry (O1, V1, K1, T2, N3). Unlike the borscht code, the initial shchi code has no pigment coordinate: this is a modeling simplification, not established evidence that color plays no categorical role.

The code maps variants into a finite-dimensional discrete space. The baseline metric is Hamming distance—the number of mismatched nominal coordinates. T1–T4 and N1–N4 are not treated as naturally ordered. A possible weighted metric, $\mathbf{d_f(Ш_i, Ш_j) = \Sigma_j\ v_j \cdot 1(Ш_i j \neq Ш_j j)}$, is separately estimated for its ability to predict perceived similarity between types. Weights **v_j** are not automatically borrowed from the Shchi Index: importance for prototype similarity and contribution to pairwise distance are different parameters. **[H]**

5.6. Place of the model in the trilogy: three category configurations

[H] The Shchi Index forms a methodological trilogy with models ИБ [47] and ИСТО [48], but the models cannot be reduced to one another:

Parameter	ИЩ (shchi)	ИБ (borscht) [47]	ИСТО (okroshka) [48]
Candidate high-weight features	Cooking integration, vegetable body (hypothesis; weights unestablished)	Flavor balance (K, S_1; hypothesis [47])	Physical parameters (X, H; hypothesis [48])
Candidate filter	None	Candidate sour–sweet block; numerical filter $K \geq 0.5$ and $S_1 \geq 0.5$ removed in revision 1.0 [47]	Candidate threshold of physical typicality, not membership: $X \geq 0.5$ and $H \geq 0.5$ [48]
Working index threshold	None (threshold-free model)	Unestablished; numerical ИБ ≥ 0.6 threshold removed in revision 1.0 [47]	ИСТО ≥ 0.6: a pilot region of high typicality, not a membership threshold [48]
Acidity	Optional axis; unknown weight before calibration	Candidate strong predictor; necessity unestablished [47]	Variable axis with a substitutable carrier (K axis + code O) [48]
Multifunctional carrier	Sauerkraut (V, K, T)	Beet ($Ц^1$, S_1, S_2, T)	Kvass (O, K, Г)
Type code	Щ = (O, V, K, T, N)	Б = (Ц, К, Б, Т, С)	Ок = (О, Х, Н, П, К)
Convergent analogue/control	Kapusnyak	Gazpacho / *luosong tang*	Tarator / *šaltibarščiai* / gazpacho

Note. The multifunctional carrier row for ИСТО lists carbonation (Г), which is a modifier, not an index axis. Identical letters across models need not denote identical variables: О_щ means liquid soup form, whereas О_ок refers to the liquid-base type in okroshka. The definitions needed to interpret [47, 48] are summarized in the table; complete verification requires consulting the separate manuscripts.

The trilogy’s hypotheses are mutually testable: acidity’s weight in the Shchi Index must be estimated; in the borscht model it is proposed as a strong predictor; in okroshka the acid carrier changes. Compensatory architectures are tested separately in each work. Cross-category comparisons are valid only with identical preparation, participant-selection, and analysis procedures. Symmetry among the three configurations is a **hypothesis of the trilogy, not an established fact**, and experimental results may undermine it.

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6. Conclusions from the Analysis: What the Model Assumes

The study's suppositions (levels [T] and [H]) are brought together explicitly below. They are propositions the model *makes*, not propositions that the sources *prove*:

1. Sensory sourness in shchi is not determined by pH alone. Within controlled ranges the relationship may be monotonic, but its size and shape depend on acid identity and concentration and on the food matrix (fat, sugars, salt, umami).
2. Fermented food matrices may have different sensory profiles from reconstructed acid systems matched on pH or TA. Any residual difference after reconstruction of known components is assigned to unreconstructed product properties only within the limits of Experiment 2's design.
3. Cabbage is a multifunctional carrier, but available sources establish neither its necessity nor its sufficiency for identifying a dish as shchi. The hypothesis that the combination of O, V, K, T, and N adds predictive information is tested separately.
4. The Shchi Index models putative structural–sensory similarity rather than defining cultural membership. Differently named dishes may have identical vectors; this may reflect cultural labeling, omitted sensory attributes, or inadequate operationalization of the existing axes.
5. Historical material (etymology [33], seasonal substitutions [35, 36], Carroll's observation [42]) is **consistent** with certain model premises but does not verify the model. Predictive and psychological claims can only be confirmed experimentally.

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7. Falsifiable Predictions

The model generates nine testable predictions, each with a falsification condition.

- **P1.** At equal pH, different acid systems (vinegar / brine / tomato / kvass) will differ on a prespecified primary sensory outcome. *Falsification:* equivalence is demonstrated within prespecified margins at matched pH.
- **P2.** At equal titratable acidity, different acid systems will likewise differ on a prespecified primary sensory outcome. *Falsification:* equivalence is demonstrated within prespecified margins at matched TA.
- **P3.** Fermented carriers (brine, sauerkraut, fermented green tomato) will differ from reconstructed systems on at least one prespecified A_s component in separate series matched either on pH or on TA. *Falsification:* equivalence within prespecified margins is confirmed for all primary components in both series. Simultaneously equal pH and TA across differently buffered matrices is not assumed.
- **P4.** A standard dose of smetana will alter a prespecified primary sensory outcome more than volume-matched and compositionally specified fat/isocaloric controls. Primary analysis estimates the total effect of smetana addition. Postaddition pH and TA are treated as possible mediators; simple statistical adjustment for them is not interpreted causally as an "effect beyond pH/TA." *Falsification:* differences from all controls lie within prespecified equivalence margins.
- **P5.** The combined structural features O, V, K, T, and N will predict "shchi" identification better than cabbage presence alone on an independent validation sample. *Falsification:* the complete model's improvement on a prespecified metric falls below the required threshold. P5 concerns predictive value of multiple axes, not proof of psychological prototype organization.
- **P6.** In a factorial subseries, increasing one axis when another is low will raise identification probability by at least a prespecified minimum. This conditional compensatory contrast can also occur in an additive model. A stronger nonadditive-compensation hypothesis is separately tested by an interaction: the increased axis has a greater effect when the weakened axis is low. *Falsification:* the confidence

interval excludes the minimum conditional gain; for the stronger version, it excludes the prespecified interaction. Mere nonsignificance in an underpowered test does not count as falsification.

- **P7.** Strengthening P3, the fermented-carrier versus reconstructed-system difference will persist in a **visually blinded subseries** using the same matching criterion (pH or TA). *Falsification:* equivalence is confirmed after visual information is excluded. A remaining difference concerns aggregate nonvisual perception; it does not isolate taste from odor, texture, or trigeminal signals.
- **P8.** In a prespecified K×T×N factorial subseries, when K is low, samples high in T and N will have a greater identification probability than samples low in both T and N. This simple conditional contrast tests practical compensation. A separate difference-in-differences contrast tests whether the joint T and N effect is greater at low K than at high K. *Falsification:* the confidence interval for the conditional contrast excludes the minimum effect; for the nonadditive version, the difference-in-differences interval excludes the prespecified magnitude.
- **P9.** With the physical sample held constant, a randomly assigned "shchi" or "kapuśniak" label will not change the probability of a "shchi" identification by more than a prespecified margin, if the five-axis structure is practically sufficient for categorization. The competing cultural–contextual hypothesis predicts a directional labeling effect: "shchi" increases and "kapuśniak" decreases the probability of a "shchi" response. *Falsification of structural sufficiency:* both within-dish labeling effects exceed the minimally meaningful effect in the predicted direction, or labeling materially improves held-out predictive quality beyond O, V, K, T, and N. *Falsification of the practically significant alternative:* confidence intervals for within-dish effects are wholly contained within a prespecified equivalence region. P9 does not posit structure and culture as logically incompatible causes: intermediate findings may support contributions from both.

Effect sizes. Before the main series, one primary outcome per hypothesis family, a minimally meaningful effect, and an equivalence margin are fixed. If multiple A_s components are jointly primary, a multiplicity or hierarchical-testing rule is prespecified. Continuous outcomes use Hedges' g, with explicit specification of the standardization method for repeated clustered designs. "0.5 points" refers only to a raw difference on a 0–10 scale and is not called d. For P1–P3 and P7, $|g| \geq 0.5$ may guide power planning, but final thresholds are refined using pilot variance before seeing main-series outcomes. For P5, a validation metric and minimum change in area under the curve (ΔAUC) are prespecified; for P6/P8, minimum interaction contrasts or differences in identification probability; for P9, a minimum practically important absolute probability difference following relabeling. The numerical P9 margin cannot be deduced from the literature and must be preregistered before examining main-series results. Evidence of no effect requires an equivalence test or sufficiently narrow confidence interval, not merely a nonsignificant p-value.

7.1. How to interpret negative results

A null or negative result need not refute the entire model; it localizes failure to a particular arrow in the causal scheme (§3.3). Interpretations are prespecified:

Negative result	What it falsifies	What it does NOT falsify
Reconstructed systems and fermented carriers are equivalent on prespecified primary A_s components in both matched series (P3), including after visual blinding (P7)	Residual sensory difference between real product and reconstruction within tested margins	Differences in C_abs/C_rel; fermentation's practical value for preservation or other properties
Total smetana effect is equivalent to volume and fat/isocaloric controls (P4)	Additional total effect of smetana relative to the chosen controls	Its traditional role; separate pathways via pH, TA, protein, fat, emulsion, or texture

Negative result	What it falsifies	What it does NOT falsify
Complete model does not outperform "cabbage present/absent" (P5)	Predictive value of the multi-axis Shchi Index in that sample	Prototype organization as such (axes or weights rather than the framework may be wrong)
P9 labeling effects exceed minimally meaningful size and improve prediction beyond structural axes	Practical sufficiency of O, V, K, T, N for categorization	Structural similarity or a possibly independent contribution from the Shchi Index
P9 labeling effects are equivalent to zero within specified margins	Practically important immediate label effects under the tested conditions	Culturally learned sensory differences; transfer to other groups and contexts
Conditional-contrast intervals exclude minimum effects (P6/P8)	The particular practical compensation pathways	The set of axes or effects at other factor levels
No between-category asymmetry with borscht on acid removal	The mirror hypothesis of the paired models (H6 of [47])	The internal predictions of either model on its own

8. Experimental Program

Hierarchy of units. The experimental unit is determined by the level at which a treatment is assigned. For recipe or culinary treatment it is an independently cooked batch; for fermentation stage, an independent fermentation batch; for treatment independently assigned to aliquots, an independently treated vessel or branch; and for P9' s randomly assigned informational label, the participant or presentation, while the cooking batch serves as a stimulus block. Successive time points from the same batch and repeated ratings by a participant are repeated measures. Each experiment must specify separately the units of randomization, independent replication, and observation. A mixed model does not convert a single raw-material batch or cooking batch into independent replicates [54].

Three to five independent top-level units per condition are permitted only as a pilot for variance estimation. The main-series and panel sizes are determined by an a priori power analysis for one primary outcome that accounts for clustering. Samples are coded, presentation order is counterbalanced, and samples per session are limited through a balanced incomplete-block design. Serving temperature is selected in the pilot to be as tolerable and perceptually stable as possible for the panel. If 65 ± 2 °C is retained, the protocol must establish safety and absence of temperature discomfort, and actual serving temperature must be logged. Panel repeatability is assessed with blind replicates (weighted κ for ordinal scales and ICC for continuous ratings).

The statistical plan and contrasts are registered before the main series. Continuous instrumental outcomes are analyzed with mixed-effects models after residual diagnostics; if the normal model is unsuitable, a prespecified robust or rank-based alternative is used. Sensory ratings incorporate condition, order, and temperature effects as well as random effects of taster, cooking batch, and, where applicable, fermentation batch/lot. Binary identification is analyzed with a logistic mixed-effects model. Cooking-batch and day effects are estimated separately only when the design identifies them; otherwise a combined "day/batch" effect is used. Holm correction is applied to primary contrast families; FDR is reserved for exploratory analyses. O, V, K, T, and N are examined for collinearity. Full-model performance is assessed on held-out cooking batches and recipe types, not the observations used to choose weights.

Control-factor matrix. Sources of bias are distinguished from causal-mechanism components; the latter are measured but are not always adjusted away as "nuisance variables":

Factor	Role	Control or analysis
Serving temperature	Affects perception of sourness and volatiles	Pilot-selected safe range; thermometer reading for every serving
Visual channel	Color shapes expectations of sourness	Serving arrangement that physically prevents seeing the sample; separate control for altered aroma delivery
Presentation order and fatigue	Contrast and adaptation effects	Randomized counterbalancing; balanced incomplete blocks; pauses ≥ 2 min
Matrix (fat, salt, sugar, starch)	Part of the perceptual causal mechanism; changes composition and buffering	Standardize where a direct acid effect is targeted; model total and conditional effects separately
Cooking batch/day	Between-batch variation, common raw-material lot	Separate effects only if several cooking batches occur on at least some days; otherwise combine "day/batch" ; batch count set by power analysis
Taster phenotype	Individual differences in taste suppression [19]	Random effect (1 | taster); repeated ratings on some samples
Cultural experience and labeling	May shift categorization without changing sensation	Experience questionnaire; Experiment 0 as external calibration; randomized labeling in P9

Pilot and main series. The program has two phases. A pilot with 8–12 tasters (a typical panel size for descriptive sensory analysis) and a minimum number of cooking batches is used to refine procedures, assess panel repeatability, and estimate actual effect sizes. The main series is planned from pilot estimates, with panel and batch sizes determined by power analysis, and is expanded through informed-consent tastings by restaurant visitors (who do not replace the trained panel).

Chemical measurements. Before registering the main series, the analytical protocol must specify pH measurement temperature and two- or three-point pH-electrode calibration; titrant, endpoint, and TA units; titration range and buffer-capacity units; HPLC analyte list, sample preparation, internal standards, detection and quantification limits, technical replicates, and treatment of nondetects. pH- or TA-matching is checked in the final served aliquot at a standardized analytical temperature. C_total is calculated only after components have been put into explicitly stated comparable units; summing mass concentrations of different acids is not described as titratable acidity or acid equivalents.

Ethics and safety. The protocol undergoes ethics review before recruitment. All sensory and categorization panels require informed consent, a right to withdraw without consequences, confidentiality procedures, and exclusion criteria for allergies and contraindications. Hygiene, cooling and storage rules, and microbiological safety criteria for fermented materials are specified in advance; serving must not pose burn risks. Because P9 partially conceals the purpose of informational manipulation, that concealment must be justified and participants debriefed afterward. Dairy, gluten, mushrooms, and other relevant allergens are disclosed before consent to tasting.

Experiment 0. Pilot survey on necessary features

[H] Before the laboratory series, bearers of the tradition are asked which features they regard as mandatory for shchi (cabbage, sourness, soup form, richness, preparation technology, smetana at serving, leafy vegetable bulk). Thirty participants are acceptable only for a pilot. The main survey sample is sized according to required precision of proportions and planned comparison across cultural or age groups. Responses

measure conscious beliefs about necessary features, not the Shchi Index weights directly, and do not calibrate latent membership. The purpose is to identify differences between stated rules and identification of physical samples in Experiment 3.

Experiment 1. Stage of cabbage fermentation

Several independent cabbage fermentation batches are assigned sampling times; a standardized recipe is then reproduced in independent cooking batches. The variable is measured cabbage state: fresh / early fermentation / mature fermentation / prolonged fermentation with brine. Successive sampling points within one fermentation batch are repeated measures. Stage is defined by time, pH, TA, C_abs/C_rel and, if resources permit, the microbial profile—not by the presumed name of a dominant genus. If the stages all come from one fermentation batch, inference is confined to that batch and cannot be generalized to fermentation as a process.

Measurements: pH, TA, buffer capacity, C_abs/C_rel; sensory A_s plus balance and acceptability.

Tests: dependence of chemical and sensory profiles on measured fermentation stage. Directions of D, P, and R changes are prespecified before the main series; no single "depth" score is used.

Experiment 2. Acid type and pathway of formation (matched four-level series)

Within each independent base cooking batch, a full family Б–В–Г–А is prepared for every acidifier. The construction is replicated across a number of independent cooking batches set by power analysis. Real products represent several independent batches/lots; otherwise conclusions apply only to the selected product. Component mass, temperature, timing, and order of addition are fixed. The levels progressively reconstruct properties of the real product:

- **Б —a single dominant pure acid:** fresh shchi with one pure acid chosen after analysis of the real product;
- **В —measured-acid profile:** a pure-acid mixture reproducing HPLC-measured C_abs within analytical uncertainty;
- **Г —reconstructed matrix:** level B plus measured NaCl, sugars, solids, and other prespecified nonacid constituents;
- **А —real product:** brine, vinegar, tomato, kvass, or stewed apples.

The Б–В contrast tests a dominant acid versus the mixture of measured acids; В–Г estimates the combined contribution of added known nonacid components; Г–А measures the remaining difference between reconstruction and product. The last contrast does not identify its specific cause: volatile compounds, texture, colloidal structure, and unmeasured substances may all differ. Two separate matched series are conducted, one matching pH and the other TA. The nonmatching quantity is measured as an outcome in each series; treating it as a covariate is permissible only for a prespecified conditional effect, not automatically. Equal pH and TA cannot simply be asserted simultaneously in differently buffered matrices.

Control: fresh cabbage plus lactic acid. **Visually blinded subseries:** selected comparisons are repeated with a presentation that physically prevents viewing the sample surface; an opaque open vessel does not itself provide blinding. If a closed vessel is used, its effects on aroma delivery are separately controlled. Visual information is excluded, but smell, texture, and trigeminal signals remain. **Green-tomato line:** fresh and fermented green tomatoes form a within-ingredient comparison only with comparable initial lots; sauerkraut remains an external comparator. **P4 subseries:** a standardized smetana dose, a volume control, and a prespecified fat/isocaloric control are added to base servings from multiple independent cooking batches. Postaddition pH, TA, and composition are measured. The primary estimand is smetana's total effect relative to the chosen controls; any remaining difference cannot be ascribed to a unique "matrix mechanism," because acidity, proteins, buffering, emulsion, viscosity, aroma, and color may remain unmatched. Mediation is analyzed separately.

Tests: P1–P4 and P7.

Experiment 3. Categorization, cultural labeling, and Shchi Index calibration

The panel is **not informed** of the Shchi Index model. Samples include classic sour shchi, fresh shchi, green shchi, nettle shchi, chard shchi, kapusnyak, rassolnik, green-tomato shchi, vegetable soup, and borscht.

Categorization questions: binary identification ("Do you classify this sample as shchi?"), graded similarity on a 0–10 scale, and separate confidence on a 0–3 scale. Confidence is not a signed membership measure: "definitely not shchi" can be a highly confident answer. Entropy of the group response proportion, $\mathbf{H = -p \cdot \log_2 p - (1-p) \cdot \log_2 (1-p)}$, with $\mathbf{0 \cdot \log_2 0 = 0}$, measures disagreement between people, not uncertainty within an individual and not the existence of a "true" boundary. Thus peripherality is assessed jointly using group dispersion, individual confidence, and graded similarity. Sensory descriptors are supplied by a separate trained panel, while categorical responses come from an expanded panel of tradition bearers. Acid-removal comparisons with borscht [47] require harmonized preparation, recruitment, and analysis before cross-category inference. Sample sensory features are recorded in parallel and O, V, K, T, and N rated independently.

P5 analysis: axes are rated by a separate trained panel or coded from prespecified recipe/technology criteria; they are not derived from the same similarity judgments. T is coded from the cooking protocol, not inferred from blind tasting. ИЩ_rule, S_proto, and the exemplar model are specified before validation and fitted on training cooking batches and recipe types. Two generalization targets are distinguished: (1) new batches of known recipe types, where a recipe-identity baseline is permissible; and (2) entirely new recipe types, where the identity of the excluded type is unknown and cannot be used as a predictor. For the latter, nested leave-one-recipe-type-out validation is performed, with all model selection inside training folds. The ten listed types are insufficient for stable comparison of high-dimensional models, so the number of independently represented types must be increased based on simulation power analysis or model complexity prespecified downward. Full models are compared with "cabbage present/absent," acidity alone, cabbage plus acidity, and directly measured sensory descriptors. Such comparisons test multi-axis prediction, not psychological prototype organization.

Discriminating P9 test: structure versus explicit labeling. Classic sour shchi (S) and standardized *kapuśniak* (K) are each produced in several independent cooking batches. Aliquots from every batch are randomly assigned to three informational conditions: no name, the name "shchi," or the name "kapuśniak." This yields a 2-physical-recipe × 3-label design: $\mathbf{S_0}$, **SЩ**, **SК**, $\mathbf{K_0}$, **KЩ**, **KК**. The informational-treatment randomization unit is the participant or presentation; batch is a stimulus block. No participant receives the same recipe under different names. Familiarity with both terms and understanding of *kapuśniak* are measured before randomization; foreign orthography is separately evaluated as a possible cue for "non-Russian dish." The primary analysis includes all randomized participants. Suspected awareness of the study purpose is considered only in a prespecified secondary sensitivity analysis, since posttreatment exclusion may introduce bias. This test causally estimates effects of the presented label but does not in itself isolate cultural learning or rule out semantic priming and demand characteristics. To help distinguish these mechanisms, a neutral or fictitious foreign label not naming a competing category is added.

The primary P9 outcome is binary "shchi" identification. Main contrasts are **Δ_L^S = P("shchi" |SЩ) − P("shchi" |SК)**, **Δ_L^K = P("shchi" |KЩ) − P("shchi" |KК)**, the unlabeled recipe contrast $\mathbf{\Delta_R^0 = P(\text{ "shchi" } |S_0) - P(\text{ "shchi" } |K_0)}$, and the conflict contrast **Δ_cross = P("shchi" |KЩ) − P("shchi" |SК)**. A substantially positive Δ_cross suggests that labeling overcomes the effect of physical recipe identity; a substantially negative value suggests the physical sample overcomes the opposing label; an equivalence region permits no dominant factor. A logistic mixed model includes recipe, label, their interaction, and random effects of cooking batch and participant if a participant evaluates several distinct recipes.

Before interpreting the unlabeled recipe contrast, a separate trained panel checks S and K for equivalence on O, V, K, T, and N within prespecified limits. If equivalence is not confirmed, S_0–K_0 may reflect differences on the axes and does not falsify the feature model. This condition is unnecessary for causal estimates of presented labels, since СЩ and SK, as well as КЩ and KK, are aliquots from the same physical cooking batches. Held-out batches of known types are used to compare **M_S** (O, V, K, T, N only), **M_C** (label, cultural experience, and known recipe identity), and **M_SC** (both). For transfer to a new recipe type, recipe identity is excluded from M_C. Superiority of M_SC to M_S demonstrates extra predictive value from measured informational context, not a specific cultural mechanism and not the absence of an independent structural contribution.

Prototype test: graded similarity judgments are separately examined for organization around an empirically inferred center and generalization to unseen recipes. Prototype, exemplar, and feature/rule models are compared on the same held-out data (§5.2). Graded judgments alone do not establish prototype theory. Historical dish names supply external context, not an infallible gold standard.

P6/P8 factorial subseries: keeping O and V fixed, a balanced design crosses K(low/high) × T(low/high) × N(low/high). A mixed logistic model evaluates prespecified conditional contrasts separately from interactions. Low K with high T,N versus low K,T,N tests the practical compensability of P8; difference-in-differences between K levels tests the stronger nonadditive version. A **challenge subseries** includes high-predicted-index samples that may not be identified as shchi and canonically named variants with low predictions.

Tests: P5, P6, P8, P9, and separately the category's prototype organization.

Experiment 4. Dynamics of resting (day-old shchi)

Several independent cooking batches, sampled at 0 / 6 / 24 / 48 h with documented rapid cooling, storage at ≤4 °C, and reheating to a prespecified serving temperature. Time points within a cooking batch are repeated measures, not independent specimens.

Measurements: pH, TA, buffer capacity, C_abs/C_rel; A_s plus acceptability.

Tests: prespecified changes in I, D, P, and R during resting. Analysis uses a repeated-measures model with time and batch effects; differences between any two curves without a prespecified criterion do not establish "rounding."

Venue and schedule: restaurant format

A restaurant permits control of mass, time, and temperature but does not make repeated observations independent. The study proceeds in randomized sequential blocks over several weeks: pilot; Experiment 1; separate families of Experiment 2; Experiment 4; then the calibration and independent validation parts of Experiment 3. Fermented ingredients are prepared ahead of time; ingredient lots are logged and allocated across conditions. Restaurant visitors may constitute a separate informed-consent sample but do not replace a trained sensory panel. Because of self-selection and restaurant context, conclusions from this group principally apply to that restaurant's visitors; population-level inferences require a separate recruitment design.

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9. Discussion and Limitations

Principal defensible result. The available material substantiates not an established "theory of shchi," but the separation of chemical state, sensory profile, and cultural categorization into three connected but nonidentical levels. ИЩ_rule is a preliminary linear feature score, while S_proto is a separate model of similarity to an empirical center. Their predictive superiority, psychological interpretation, and sufficiency for cultural identification have not been demonstrated; these claims are reserved for independent testing.

Testing architecture. The three-level framework distinguishes chemistry, sensory perception, and categorization. C_abs/C_rel are kept separate from A_s = (I, D, P, R). The models produce nine testable predictions. The program includes reconstructed acid systems, matrix controls, independent validation samples, and a causal test of explicit labeling.

Limitations.

1. The work is theoretical; all numerical reference values (sauerkraut acidities, pH ranges) are extrapolations from sauerkraut [2, 5, 37] and adjacent systems [14, 16, 17], level [T].
2. Most fermentation data concern northeastern Chinese cabbage [1–8, 10]; Russian practice may differ. The two-phase scheme is a simplification [10].
3. Perception is individual: the strength of taste-suppression effects depends on taster phenotype [19]; sensory scales provide averaged descriptions.
4. The soup matrix—a hot buffered medium containing a fat emulsion—differs from studied model systems. No direct measurements of shchi buffer capacity were found in the search conducted, which does not prove they do not exist.
5. Historical sources [33–36, 39, 42] are treated as compatible context, not proof; deliberate restraint is exercised on historical causal claims such as sour dressings being related to salt prices.
6. Nutritional caveat: blanching sorrel and discarding the water is not equivalent to cooking it directly in soup in terms of expected reduction of soluble oxalates. No individualized medical recommendations are offered [30, 38].
7. Before calibration the Shchi Index is conceptual. Its axes, independence assumptions, and functional form may be changed by Experiment 3 results.
8. Index axes are correlated because carriers can be multifunctional. Regression weights on correlated predictors may be unstable without collinearity diagnostics and, where needed, regularization; the statistical plan includes this provision, but the issue remains a limitation before calibration.
9. Index axes may omit important category features, especially cabbage/fermentation aroma, texture, visual information, and familiarity with names. Experiment 0 and the challenge subseries are opportunities to revise the set of axes, not merely tune their weights.
10. Multi-axis prediction is not prototype organization. Prototype, exemplar, and rule models must be compared on the same independent data; otherwise "prototype" remains an interpretation.
11. Top-level independence requires several fermentation batches and ingredient lots. Many portions or tasters cannot compensate for a single product batch.
12. Historical sources differ in evidentiary quality. Popular-science material and culinary websites may illustrate variants, but key historical statements require critical editions and primary texts with page or chapter citations.
13. Identical illustrative vectors for classic sour shchi and *kapuśniak* reveal formal indistinguishability within the five-axis space, but are not empirical results. Without P9 it is unknown whether the boundary reflects naming, omitted sensory features, or coarse axis coding.
14. The randomized labeling test has been designed but not performed. This version therefore asserts neither dominance of physical structure nor of cultural naming and reports no fictitious effects, confidence intervals, or model performance figures.
15. An explicit name immediately before an identification question may induce experimental demand. Purpose masking and sensitivity analysis reduce this risk but do not turn one laboratory manipulation into a complete account of cultural learning.

Open questions. An optimum acidity for classic shchi (analogous to sugar/acid ratio [16, 17]); quantitative changes during resting; a midpoint between shchi and borscht prototypes [47]; application to rassolnik and solyanka; temperature dependence of sourness perception in shchi; and whether umami is a modulating module (§2.3) or an independent axis in shchi and borscht models, given its asymmetric interaction with

acidity. Joint tasks for the paired studies—a shared "chemistry → sensation → category" framework, shared historical timeline, and mapping of regional variability—belong to a separate methodological article of the project and are outside the present work.

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10. Conclusions

What the sources show: cabbage fermentation is multifactorial and produces organic acids and other metabolites [1–10, 37]. pH, TA, and perceived sourness are not interchangeable [13–18]. Tomatoes and fermented green tomatoes contain several organic acids and umami-associated compounds [24–28]. Sorrel contains appreciable oxalates, but the cited sources do not permit reducing its entire sour–astringent profile to them [22, 30, 38].

What theoretical analysis substantiates: chemical state, sensory profile, and cultural identification require separate variables and cannot be substituted for one another. The Shchi Index may be used as a preliminary model of structural–sensory similarity, not a definition of cultural membership. Identical vectors for differently named dishes are possible and cannot be resolved by adjusting weights within the same set of axes.

What the model predicts: at equal I, absolute and relative acid profiles (C_abs/C_rel) and sensory A_s may differ. Fermented food matrices may differ from reconstructed systems matched on pH or TA. Cabbage is multifunctional, but its necessity for categorization is unestablished. O, V, K, T, and N may add predictive value beyond simple baselines. Index superiority, prototype organization, acidity weight, axis sufficiency, compensation, and the relative contribution of cultural labeling are hypotheses to be tested, not findings of this study.

What experiments must test: P1–P9 (§7) via a pilot survey and four laboratory–sensory experiments (Experiments 0–4), with controls, a statistical plan, and temperature management (§8). P9 distinguishes practical sufficiency of the structural model from an additional labeling effect; neither explanation is confirmed in advance.

Practical significance (conditional on confirmation): designing shchi with target chemical and sensory profiles, standardizing sour soups in food service, and supporting systematic recipe development. Comparing the models of borscht and okroshka [47, 48] may initiate a general account of categorical structure in dressed soups, but axis weights, filters, compensation, and cultural transferability require experimental establishment. This work does not prejudge the sufficiency of five axes, claim that technology or vegetable mass necessarily carries shchi identity, identify K as the weakest axis, or assert that cultural names dominate physical samples.

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11. Note on the Bibliography

The full bibliography below contains 54 entries. Sections are: I —cabbage fermentation [1–12, 37]; II — sourness perception [13–18]; III —taste interactions [19–23]; IV —tomatoes [24–29]; V —sorrel and oxalates [30, 38]; VI —history, cultural context, and category theory [31–36, 39–46]; VII —author' s related works [47, 48]; VIII —additional sources on sourness perception, taste interactions, and methodology [49–54]. Reference numbers have been retained from the previous version and are therefore not always consecutive within sections I, V, and VI.

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12. Appendices

Appendix A. Sensory-evaluation questionnaire (template)

Parameter	Scale	Comment
I —sourness intensity	0–10	Perceived
R —sourness character	Separate 0–10 scales for softness, sharpness, astringency, fruitiness, and milkiness	Attributes rated separately
Temporal profile I(t)	Continuous record or fixed points: swallowing / +10 s / +30 s / +60 s	Derive D (AUC and time to half-decay) and P (time to maximum) from the curve
Umami / brothiness intensity	0–10	Separate descriptor, not sourness "depth"
Body	0–5	Axis V
Richness	0–5	Axis N
Balance / acceptability	0–10	
Similarity to shchi	0–10	Experiment 3 question; panel is not told the model
Identification ("Is this shchi?")	Yes/no	Collected alongside graded similarity for comparability with [47]
Confidence in identification	0–3	Separate measure of certainty, not signed membership (§8, Experiment 3)
Desire to repeat	Yes/no	

Samples are identified by three-digit codes; presentation order is randomized and counterbalanced; the temperature of each serving is recorded within a safe range specified in advance; some specimens are blind replicates.

Appendix B. Illustrative matrix of Shchi Index axes (synthetic example, NOT data)

Variant	O	V	K	T	N
Classic sour shchi	1	1	1	1	1
Fresh shchi	1	1	0	1	1
Green (sorrel) shchi	1	1	1	1	0.5–1
Spring nettle shchi (reconstruction)	1	1	0.5–1	1	0–0.5
Fasting mushroom shchi	1	1	1	1	0.5
"Empty" shchi	1	1	0–1	1	0
Kapuśniak	1	1	1	1	1
Rassolnik	1	0.3	1	0.7	1
Vegetable soup	1	0.5	0	0.5	0

Values illustrate the model's logic only and have no empirical standing. Identical vectors for classic sour shchi and kapuśniak are deliberately retained as a formal boundary check: these cases cannot be distinguished using the five specified axes, but this implies neither sensory equivalence nor common cultural membership. Axis calibration and the distinguishing labeling test are tasks for Experiment 3.

Appendix C. Traceability matrix: claim → variable → experiment → falsifier

The principal testable claims are linked to their testing procedures and falsification conditions; contextual historical claims are not turned into experimental propositions:

Claim	Variable(s)	Experiment	Falsifier
Shchi sourness cannot be reduced to pH or TA	pH, TA, buffer capacity, C_abs/C_rel, A_s	Experiments 1–2	P1/P2: equivalence of A_s established in respective matched series
Fermented carriers differ from reconstructed systems	C_abs/C_rel, known matrix components, A_s	Experiment 2, Б→В→Г→А	P3: equivalence on prespecified primary components in both series
Nonvisual difference persists	A_s with ordinary presentation and physical exclusion of sample view	Experiment 2, visually blinded subseries	P7: equivalence after excluding the visual channel
Green-tomato fermentation changes product profile	Fresh and fermented tomato; C_abs/C_rel, A_s	Experiment 2, within-ingredient line	Differences absent within prespecified margins; independent acid contribution not identified
Smetana has an extra total effect relative to controls	I, R, pH/TA; volume and isocaloric/fat controls	Experiment 2, P4 subseries	Effect equivalent to controls
Cabbage fermentation stage changes profile	Measured stage; C_abs/C_rel, A_s	Experiment 1	Stage profiles equivalent within margins
Resting changes components of the profile	pH, TA, C_abs/C_rel, A_s at 0/6/24/48 h	Experiment 4	Prespecified time contrasts are equivalent
Multi-axis model predicts identification better than cabbage	O, V, K, T, N; binary identification	Experiment 3, independent validation	P5: ΔAUC below threshold
Structural axes are practically sufficient relative to immediate cultural labeling	Binary identification under fixed physical sample with randomly assigned name	Experiment 3, 2 recipes × 3 labels	P9: within-recipe label effects exceed minimum meaningful size or cultural context improves prediction beyond O, V, K, T, N
Category has graded prototype structure	Similarity, category center, generalization to unseen recipes	Experiment 3	Graded structure fails to generalize beyond training data
Axes permit compensation, in particular K→(T,N)	K×T×N factorial	Experiment 3, factorial subseries	P6/P8: intervals exclude minimum interactions/contrasts
Survey beliefs differ from sample classification	Stated necessity versus actual identification	Experiments 0 and 3	Prespecified relationship absent or opposite to prediction
Acidity is optional for identifying shchi	Identification rate after removing K	Experiment 3 plus aligned program [47]	Removing K reduces identification to a prespecified necessity criterion; no between-class asymmetry
Historical material is consistent with the model	—(context)	—	See §1.2: history does not prove structure

Use of AI tools

Large language models were used in preparing the manuscript for editing, translation, discussion of hypotheses, and literature search. Interpretations and conclusions are the author’s own.

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VI. History and Cultural Context of Russian Cuisine

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33. Vasmer M. “Shchi” // *Etymological Dictionary of the Russian Language*, 4 vols. Moscow: Progress, 1986–1987. Vol. 4, p. 506. The “shchi” entry records Old Russian *shti* (genitive *shtei*) in the *Domostroi*; proposed derivations from *sъto*, “sustenance,” or kinship with “sorrel”; dialect meanings include “cooked dish, broth, soup seasoned with cabbage, sorrel, and other greens.” URL: https://www.slovorod.ru/etym-vasmer/vas-sc.htm
34. *Domostroi* / ed. V. V. Kolesov and V. V. Rozhdestvenskaya; general editor L. A. Dmitriev. Saint Petersburg: Nauka, 1994 (*Literary Monuments*). Sixteenth century (1550s): references to *shti* (Silvester

recension: “shti, rye porridge” on fasting days; according to Vasmer [33], Domostr. Zab. 55 ff.; K. 41), “kislashchyanoy” (per [33], Domostr. K. 28); sour shchi as a beverage. See also [35].

35. “A Hearty Dish with Greens: The History and Recipe of Shchi, a Hallmark of Russian Cuisine” // *Vokrug sveta*. 2024. URL: https://www.vokrugsveta.ru/article/266829/ (etymology; cabbage in Rus’ from the ninth century; seasonal shchi cycle; sour dressings including brine, stewed sour apples, and smetana as substitutes for costly salt; Russian-stove preparation; cites M. Syrnikov’ s *Authentic Russian Food* and shchi with bracken fern).

36. “Shchi from Dawn to Dusk” / *Food with History* (with commentary by culinary historian P. Syutkin). URL: https://p-syutkin.livejournal.com/801113.html (*Domostroi* in the 1550s; rye-flour slurry and replacement by potato; seasonal substitution sauerkraut → nettle, sorrel → young cabbage; Russian stove; proverbs).

37. Pokhlebkin V. V. *National Cuisines of Our Peoples*. Moscow: Pishchevaya promyshlennost, 1978.

38. *Kapuśniak* / kapusnyak and related soups: “Kapusnyak —Ukrainian Sauerkraut Soup” // *Kitchen Epiphanies*. URL: https://www.kitchenepiphanies.com/kapusnyak-ukrainian-sauerkraut-soup/ (kapusnyak presented as the second most significant Ukrainian soup; links to Zaporozhian Cossack cuisine, fifteenth–eighteenth centuries; Polish *kapuśniak*, Slovak *kapustnica*; adjusting sourness through brine quantity and washing cabbage); “Kapusniak (Ukrainian Sauerkraut Soup)” // *Budget Bytes*. 2022. URL: https://www.budgetbytes.com/kapusniak/

39. Birch-bark letter No. 1159 (Novgorod; fragment of a deed of sale; conventional date 1400–1410, stratigraphic date late fourteenth to first quarter of fifteenth century) // *Old Russian Birch-Bark Letters*, online database of HSE University and the Institute of Slavic Studies of the Russian Academy of Sciences. URL: https://gramoty.ru/birchbark/document/show/novgorod/1159/ (reading: “…[l]omu [go]rodu [i] kapustu / …[n]a to poslukho”). Cf. Sichinava D. “Birch-Bark Letters—2023: Boyars, Cabbage, Mir, Zhir, and Pir” // *Arzamas*. 29 November 2023. URL: https://arzamas.academy/mag/1224-beresta23 (context and interpretation).

40. Carroll L. (Dodgson C. L.) *The Russian Journal: A Record of a Tour in Russia in 1867* / Russian translation: *Diary of a Journey to Russia in 1867*. His first tasting of shchi (“shtshee”) is described as “quite drinkable” ; the present Russian manuscript renders this as “вполне пригодными для питья.” The entry dates to late July 1867 (entry into Russia and arrival in St Petersburg on 26–27 July; tasting described en route); the precise diary-entry date requires verification against a printed edition. Russian translation excerpts: https://biography.wikireading.ru/193795; travel context: https://afisha.london/en/2023/06/30/lewis-carroll-in-19th-century-russia-monasteries-theatres-and-russian-shchi/

41. Gogol N. V. *Dead Souls*. 1842. Part 1, ch. 1: “День, кажется, был заключен порцией холодной телятины, бутылкой кислых щей и крепким сном во всю насосную завертку…” (quoted from the academic edition: *Complete Works*, 14 vols. Moscow/Leningrad: USSR Academy of Sciences, 1937–1952, vol. 6; evidence of “sour shchi” meaning a beverage; see https://chgbiblio.ru/archives/65532).

42. Pushkin A. S. “Fragments from Onegin’ s Journey” // *Eugene Onegin*. “Мой идеал теперь —хозяйка, / Мои желания —покой, / Да щей горшок, да сам большой”(based on the proverb “I eat plain food, but I am my own master” ; text and commentary: https://nabokov-lit.ru/nabokov/kritika-nabokova/evgenij-onegin/otryvki-iz-puteshestviya.htm).

43. Wittgenstein L. *Philosophical Investigations* // *Philosophical Works*, Part 1. Moscow: Gnozis, 1994 (§§65–71 on family resemblance, used for harmonization with the companion categorical framework [47]).

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VII. Related Works by the Author

47. Koriakin A. N. *Borscht as a Historically Variable Set of Named Dishes: Lexical Continuity, Structural Similarity, and a Program for Empirical Testing*. Research manuscript, revision 1.0, 2026. (Methodological companion: candidate Borscht Index [ИБ], functional substitutes, raw material as an independent variable.)

48. Koriakin A. N. *Okroshka as a Multifactorial Culinary System: A Model of Structural–Sensory Typicality and a Program for Testing Categorical Identity*. Research manuscript, revision 1.0, 2026. (Third study: index of structural–sensory typicality of okroshka [ИСТО], type code Ок = (О, Х, Н, П, К), candidate physical-typicality threshold X ≥ 0.5 and H ≥ 0.5—not membership; §5.5.)

VIII. Additional Sources on Taste Interactions and Methodology

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