

# The Molecular Gastronomy and Agronomic Synthesis of Chickpea Butter Masala

## Introduction to the High-Fidelity Culinary Translation

The conceptualization and execution of Murgh Makhani—globally recognized as Butter Chicken—into a plant-based, nutritionally optimized paradigm using the garbanzo bean (*Cicer arietinum* L.) requires a rigorous synthesis of agricultural science, physical chemistry, and molecular gastronomy. The creation of an authentic Chickpea Butter Masala within the specific geographical, climatic, and infrastructural context of Berlin, Germany, introduces highly specific variables that must be systematically managed. From navigating the agronomic limitations of cultivating warm-season legumes in Pleistocene-derived Arenosols to overcoming the physiochemical barriers posed by Berlin's notoriously hard municipal water, every step of the culinary and agricultural process demands precise biochemical intervention.

This comprehensive report details the complete lifecycle of Chickpea Butter Masala. It evaluates the localized cultivation and post-harvest dynamics of chickpeas, followed by the manipulation of their cellular architecture through alkaline soaking and high-pressure thermal processing. Furthermore, it analyzes the procurement and extraction of volatile aromatic compounds from locally cultivated European spices in Berlin, the thermodynamic properties and extraction methodologies of homemade cultured ghee, and the complex rheological mechanics required to stabilize a cashew-tomato emulsion using the traditional *bhunao* technique.

## Agronomic Foundations and Post-Harvest Dynamics of *Cicer arietinum* in Berlin-Brandenburg

The foundation of any superior culinary output is the structural and chemical integrity of its raw ingredients. Cultivating *Cicer arietinum* L. (chickpeas) in the Berlin-Brandenburg region (USDA Hardiness Zone 7b) presents a unique set of pedological and meteorological challenges that ultimately dictate the biochemical profile, cooking time, and textural viability of the harvested seed<sup>1</sup>.

### Soil Pedology, pH Management, and Biological Nitrogen Fixation

The agricultural landscape surrounding the Berlin metropolitan area is dominated by coarse-textured, Pleistocene-derived glacial sands and sandy loams known as Arenosols<sup>1</sup>. These soils frequently exhibit critically low agricultural yield indices, commonly rated between 25 and 40 *Bodenpunkte*, indicating high permeability and low inherent fertility<sup>1</sup>. While the high macroporosity of these soils ensures excellent aeration—a significant advantage given the chickpea's acute sensitivity to hypoxic waterlogging and subsequent root-rot—it simultaneously results in an exceptionally low Available Water Capacity (AWC)<sup>1</sup>.

To thrive in these low-nutrient sandy matrices and accumulate the 19.44% to 22.7% crude

protein necessary for human nutritional requirements, chickpeas rely entirely on biological nitrogen fixation (BNF)<sup>1</sup>. Because native European soils lack endemic populations of the highly specific rhizobial symbionts required by chickpeas, the seeds must be artificially inoculated with *Mesorhizobium ciceri* or *M. mediterraneum* prior to sowing<sup>1</sup>. When properly nodulated, the chickpea plant synthesizes high levels of essential amino acids and complex carbohydrates, banking these reserves in the cotyledons<sup>1</sup>.

However, the native pH of poorly buffered glacial sands in the Brandenburg region frequently drops below 5.5 due to the continuous leaching of basic cations driven by winter precipitation<sup>1</sup>. When the soil pH falls below 5.5, structural aluminosilicate minerals in the clay fraction undergo rapid acid hydrolysis, releasing highly phytotoxic trivalent aluminum cations ( $Al^{3+}$ ) into the soil solution<sup>1</sup>. Aluminum toxicity is catastrophic for *Cicer arietinum*; the  $Al^{3+}$  cations physically bind to the negatively charged pectins in the root apex, instantly ceasing cell division and elongation<sup>1</sup>. This results in stunted, coralloid root systems incapable of scavenging deep moisture reserves during summer droughts<sup>1</sup>. To mitigate this, local agronomists must utilize engineered biochar to buffer the localized rhizosphere pH and permanently elevate the cation exchange capacity of the sandy matrix, providing a hospitable microenvironment for root expansion and rhizobial proliferation<sup>1</sup>. Concurrently, chickpea roots actively exude citrate, a low-molecular-weight organic acid that functions as a potent biological chelating agent, complexing with  $Al^{3+}$  to reduce its phytotoxicity while increasing the bioavailability of phosphate ions<sup>1</sup>.

## Thermal Kinetics and Growing Degree Days (GDD)

The temporal sequencing of chickpea development from seedling emergence to physiological maturity in Berlin is governed by the accumulation of thermal energy, quantified as Growing Degree Days (GDD)<sup>1</sup>. The mathematical model for GDD assumes that the plant development rate is directly proportional to temperature within a specific linear range, bounded by a base temperature ( $T_{base}$ ) below which development ceases.

*Cicer arietinum* evolved in the Fertile Crescent and is genetically adapted as a cool-season crop, utilizing a lower  $T_{base}$  of  $5^{\circ}C$  for phenological modeling<sup>1</sup>. Modern chickpea varieties require between 1,287 and 1,612 GDD to reach physiological maturity<sup>1</sup>. Berlin and the wider Brandenburg region experience average annual extreme minimum temperatures ranging between  $-15^{\circ}C$  and  $-12.2^{\circ}C$ , delineating a reliable frost-free window of approximately 136 to 137 days<sup>1</sup>. This temporal window perfectly accommodates the 1,480 GDD typically accumulated between April and September, provided the seeds are precision-drilled (2.5 to 4.0 cm deep) during the late April to early May sowing window when soil temperatures consistently reach  $10^{\circ}C$  to  $15^{\circ}C$ <sup>1</sup>.

The spatial geometry of the sowing is equally critical for disease management. The paramount biological threat to chickpea cultivation is Ascochyta blight, a highly destructive foliar disease

caused by the necrotrophic fungus *Ascochyta rabiei*<sup>1</sup>. The primary vector for disease transmission is rain-splash dispersal. Epidemiological modeling demonstrates that rain-splash dispersal exhibits a critical breakpoint at an event rainfall of just 1.1 mm, above which the kinetic energy of falling raindrops physically ruptures fungal pycnidia, aerosolizing spore-laden droplets into the canopy<sup>1</sup>. Maintaining a wide inter-row spacing of 45 to 60 cm is an architectural necessity to facilitate rapid canopy drying, physically disrupting the minimum 6 to 10 hours of leaf wetness required for the conidia to germinate and girdle stems<sup>1</sup>.

| Agronomic Parameter | Berlin-Brandenburg Context                  | Mechanism of Action / Consequence                                                                          |
|---------------------|---------------------------------------------|------------------------------------------------------------------------------------------------------------|
| Soil Pedology       | Sandy Arenosols (pH < 5.5)                  | Induces $Al^{3+}$ toxicity; requires biochar buffering and <i>Mesorhizobium</i> inoculation <sup>1</sup> . |
| Thermal Kinetics    | 1,287 – 1,612 GDD ( $T_{base} 5^{\circ}C$ ) | Seed maturation aligns with the 137-day frost-free operational window <sup>1</sup> .                       |
| Spatial Geometry    | 45-60 cm inter-row spacing                  | Mitigates <i>Ascochyta rabiei</i> rain-splash dispersal kinetics <sup>1</sup> .                            |
| Target Plant Stand  | 33-44 seedlings/m <sup>2</sup>              | Balances early canopy closure with limited available water capacity <sup>1</sup> .                         |

## European Regulatory Constraints, Vine-Curing, and the HTC Defect

As the legumes transition into late summer, the focus shifts from primary biomass accumulation to the physiological desiccation of the seed. In conventional agriculture globally, chemical desiccation is frequently employed utilizing systemic herbicides like glyphosate to kill the foliage and force uniform crop dry-down<sup>1</sup>. However, within the European Union, strict Maximum Residue Limits (MRLs) and organic regulations (Regulation (EU) 2018/848) render pre-harvest chemical desiccation a high-risk or entirely forbidden practice<sup>1</sup>.

Consequently, Berlin-grown chickpeas must undergo a physical vine-curing process. The crop is harvested at 80% to 90% leaf drop when the seeds have reached physiological maturity—possessing an internal moisture content of roughly 30%<sup>1</sup>. The plants are physically severed from the soil and hung on racks or mesh screens for 7 to 14 days<sup>1</sup>. This natural atmospheric curing forces a slow, highly synchronized reduction in moisture. Rapid thermal artificial drying leads to irreversible seed coat cracking (Mechanical Damage Susceptibility),

which critically degrades the structural integrity of the legume<sup>1</sup>. Vine-curing also permits residual complex carbohydrates located in the vascular tissues of the stem to translocate into the seed, maximizing final seed weight<sup>1</sup>.

Once the internal moisture drops to a critical window between 16% and 22%, the crop is mechanically threshed. To preserve the structural integrity of the beans, the combine harvester's threshing cylinder speed must be meticulously calibrated between 150 and 300 revolutions per minute (rpm), and the concave clearance opened to approximately 1.6 cm<sup>1</sup>.

Following threshing, post-harvest storage thermodynamics heavily influence the culinary viability of the legume. If chickpeas are subjected to elevated temperatures (consistently  $> 25^{\circ}\text{C}$  )

and high relative humidity ( $> 65\%$  ) during storage, they undergo severe physiological deterioration known as the Hard-to-Cook (HTC) defect<sup>1</sup>. The HTC phenomenon is driven by the secondary lignification of cotyledon cells and the enzymatic cross-linking of pectic substances in the middle lamella<sup>1</sup>. This cross-linking is mediated by phytase activity, which releases calcium and magnesium ions that form insoluble pectate bridges, permanently locking the cell walls and severely restricting water imbibition during culinary processing<sup>1</sup>. To prevent this debilitating

defect, chickpeas must be stored in cool environments (optimally below  $20^{\circ}\text{C}$  ) with strictly regulated ambient water activity ( $a_w < 0.65$  )<sup>1</sup>.

## The Physical Chemistry of Hydration, Oligosaccharide Degradation, and Gelatinization

The transformation of a desiccated, stone-hard legume into a tender, creamy component suitable for a rich Makhani gravy requires aggressive physiochemical intervention. This is particularly crucial in Berlin, where the municipal tap water presents a significant chemical barrier to legume hydration.

### The Biochemistry of Berlin's Hard Water and Pectin Rigidity

The outer seed coat (testa) and the internal cellular matrices of the chickpea cotyledon are bound together by pectin, a complex structural heteropolysaccharide<sup>1</sup>. Pectin functions as the biological cement maintaining cell wall rigidity<sup>5</sup>. Berlin's municipal tap water is classified as hard, meaning it contains high concentrations of dissolved divalent cations, primarily calcium ( $\text{Ca}^{2+}$  ) and magnesium ( $\text{Mg}^{2+}$  )<sup>7</sup>.

When chickpeas are soaked or boiled in hard water, these calcium and magnesium ions undergo an ion-exchange reaction, bonding directly with the carboxyl groups of the pectin molecules<sup>5</sup>. Depending on the specific pectin structure, gelation and rigidity result from coordinate bonding with  $\text{Ca}^{2+}$  ions or hydrogen bonding and hydrophobic interactions<sup>9</sup>. In low-methoxyl pectin, gelation results from ionic linkage via calcium bridges between two carboxyl groups belonging to two different chains in close contact with each other<sup>9</sup>. This interaction creates rigid calcium-pectate cross-links, effectively reinforcing the cellular structure

of the bean<sup>5</sup>. The resulting microstructural cement prevents water from penetrating the cotyledon, rendering the chickpeas stubbornly hard and triggering a "forever-boil" cycle regardless of thermal exposure<sup>5</sup>.

## **Alkaline Intervention: The Role of Sodium Bicarbonate ( $NaHCO_3$ )**

To bypass the limitations of hard water and rapidly tenderize the chickpea, an alkaline soaking and cooking medium must be established utilizing sodium bicarbonate ( $NaHCO_3$ )<sup>5</sup>. The introduction of sodium bicarbonate alters the chemistry of the hydration process through two primary mechanisms:

1. **Cation Displacement and Ion Exchange:** In an alkaline environment, the monovalent sodium ions ( $Na^+$ ) from the baking soda actively replace the rigid divalent calcium ions ( $Ca^{2+}$ ) bound to the pectin<sup>12</sup>. Because sodium only forms single bonds, it cannot bridge adjacent pectin molecules. This dynamic disrupts the structural integrity of the calcium-pectate network, increasing the proportion of amorphous regions within the seed and allowing rapid water imbibition into the center of the cotyledon<sup>5</sup>.
2. **Hemicellulose Solubilization:** The elevated pH (typically shifting the water to a pH of approximately 8.0 to 10.0 depending on concentration) accelerates the hydrolysis and solubilization of hemicellulose within the seed coat<sup>6</sup>. While cellulose, lignin, and pectin contents generally increase during the cooking phase, hemicellulose shows a drastic decrease of up to 26.8% when processed in alkaline conditions<sup>16</sup>. This causes the tough outer skins to detach, dissolve, and float to the surface—a critical requirement for achieving the ultra-smooth, creamy texture expected in high-end Makhani preparations<sup>5</sup>.

The standard protocol dictates utilizing approximately 1 teaspoon of sodium bicarbonate per pound of dried chickpeas during an 8-to-12 hour soak<sup>5</sup>. For maximum skin degradation, culinary professionals frequently employ a "dry-sauté" method wherein the soaked, drained chickpeas are briefly toasted in a dry pan with an additional ½ teaspoon of baking soda for 2-3 minutes<sup>5</sup>. This concentrated alkaline environment attacks the skins directly before fresh boiling water is introduced<sup>5</sup>.

## **Enzymatic and Chemical Degradation of Oligosaccharides (RFOs)**

Beyond physical softening, the hydration phase is critical for the removal of anti-nutritional factors, specifically the Raffinose Family of Oligosaccharides (RFOs). Raw chickpeas contain substantial levels of oligosaccharides, including raffinose, stachyose, verbascose, and ciceritol<sup>3</sup>.

Because the human gastrointestinal tract lacks the enzyme  $\alpha$ -galactosidase, these RFOs pass undigested into the large intestine, where anaerobic bacterial fermentation produces significant volumes of hydrogen gas, leading to flatulence and abdominal distension<sup>19</sup>.

The combination of an extended alkaline soak and subsequent thermal processing effectively neutralizes these compounds. Because oligosaccharides are highly water-soluble, soaking facilitates rapid diffusion. Studies indicate that soaking legumes in a 2% sodium bicarbonate solution for 16 hours can reduce raffinose by up to 73.8%, stachyose by 70.27%, and

verbasco by 51.71%<sup>22</sup>. The kinetics of this removal are highly temperature and pH-dependent. Steeping at lower temperatures ( $30^{\circ}C$  and  $45^{\circ}C$ ) favors the endogenous enzymatic hydrolysis of  $\alpha$ -galactosides, whereas steeping at higher temperatures ( $60^{\circ}C$  to  $90^{\circ}C$ ) favors physical diffusion into the soaking medium<sup>23</sup>. Soaking at  $45^{\circ}C$  at a moderately acidic pH of 4.0 for 3 hours has been shown to result in acceptable levels of  $\alpha$ -galactosides (reducing them by up to 65% in chickpeas)<sup>23</sup>. However, the use of alkaline sodium bicarbonate provides the superior dual benefit of hemicellulose degradation and rapid RFO leaching<sup>5</sup>. Consequently, it is an absolute culinary imperative to discard the soaking water and vigorously rinse the chickpeas under cold water before cooking to remove both the leached RFOs and any residual soapy flavor imparted by the baking soda<sup>5</sup>.

### High-Pressure Thermal Processing and Starch Gelatinization

Once rinsed, the hydrated chickpeas are subjected to high-pressure thermal processing (e.g., in an Instant Pot or pressure cooker at 15 psi). High-pressure (HP) treatment drastically reduces the required cooking time (typically to 15-20 minutes with a quick release) while achieving superior hydration rates (up to 93.8%) compared to the 42.5% hydration typically achieved via simple atmospheric overnight soaking<sup>24</sup>.

Under these extreme hydrothermal conditions, the complex starch matrix of *Cicer arietinum* undergoes complete gelatinization. Chickpea starch exhibits a C-type X-ray diffraction pattern, characteristic of legume starches, consisting of 30.61% to 33.55% linear amylose and 66.45% to 69.39% highly branched amylopectin<sup>26</sup>. Differential Scanning Calorimetry (DSC) thermograms

reveal that the onset ( $T_0$ ), peak ( $T_p$ ), and end ( $T_c$ ) gelatinization temperatures for chickpea starches range from  $65.6^{\circ}C$  to  $66.5^{\circ}C$ ,  $69.6^{\circ}C$  to  $71.1^{\circ}C$ , and  $75.6^{\circ}C$  to  $76.2^{\circ}C$ , respectively, with an enthalpy of gelatinization ( $\Delta H$ ) between 14.8 and 15.6 J/g<sup>27</sup>.

As the environmental temperature breaches this gelatinization threshold, the hydrogen bonds maintaining the semi-crystalline integrity of the starch granules rupture<sup>26</sup>. Water rushes into the granules, causing exponential swelling until the linear amylose chains leach out into the surrounding aqueous phase<sup>26</sup>. This process not only fundamentally tenderizes the cotyledon, but the leached amylose acts as a natural hydrocolloid, providing inherent thickening power and viscosity to the final Makhani sauce when the chickpeas are incorporated<sup>28</sup>.

Furthermore, high-pressure cooking is highly efficient at degrading phytic acid (myo-inositol 1,2,3,4,5,6-hexakisphosphate). While phytic acid strongly binds to multivalent cations such as zinc, magnesium, iron, and calcium, rendering them biologically unavailable, HP cooking can reduce phytic acid levels to just 0.2%—an 80% reduction from raw states—while simultaneously neutralizing trypsin inhibitors, vastly improving the nutritional bioavailability and protein digestibility of the final dish<sup>24</sup>.

| Processing Phase         | Chemical Mechanism                                          | Physiological/Culinary Outcome                                                                             |
|--------------------------|-------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|
| Hard Water Exposure      | $Ca^{2+}$ and $Mg^{2+}$ bind to carboxyl groups of pectin   | Forms rigid calcium-pectate bridges; prevents bean softening <sup>5</sup> .                                |
| $NaHCO_3$ Soak (pH 8-10) | $Na^+$ displaces $Ca^{2+}$ ; hemicellulose hydrolysis       | Destroys pectate rigidity; dissolves seed coats for ultra-smooth texture <sup>5</sup> .                    |
| RFO Leaching             | Diffusion and enzymatic hydrolysis of stachyose/raffinose   | Removes flatulence-causing compounds (up to 73% reduction) <sup>22</sup> .                                 |
| High-Pressure Thermal    | Exceeds $T_p$ ( $69.6^\circ C$ – ); ruptures hydrogen bonds | Complete starch gelatinization; amylose leaching thickens sauce; 80% phytic acid reduction <sup>24</sup> . |

# The Procurement, Biochemistry, and Thermodynamics of Spice Blooming

The aromatic architecture of Chickpea Butter Masala relies heavily on the precise integration of ground spices, notably coriander and cumin, finishing with the herbaceous warmth of *Kasuri Methi* (fenugreek leaves). In the context of Berlin, sourcing locally grown or specialized imported spices provides a unique biochemical profile, which must be activated through careful thermodynamic processes.

## Local Procurement in Berlin and Climatic Profiling of Coriander

Sourcing high-quality spices in Berlin requires navigating local markets and specialized purveyors. Establishments such as Markthalle Neun (in Kreuzberg), Spice Village (in Tempelhof), and AnuHita Groceries serve as critical procurement nodes for organic and specialized Indian ingredients, while boutique blenders like Altes Gewürzamt provide regionally grown European variations<sup>31</sup>.

Coriander (*Coriandrum sativum*) is traditionally associated with tropical and subtropical cultivation, but it is successfully grown as a summer annual in temperate regions of Germany, notably in Bavaria, Thuringia, and the Churfranken region along the lower Main<sup>35</sup>. The biochemical composition of coriander seed essential oil is exquisitely sensitive to environmental factors. Gas chromatography-mass spectrometry (GC-MS) analyses demonstrate that the dominant volatile compound in all coriander is linalool, an oxygenated monoterpene responsible

for the spice's characteristic floral, citrusy, and slightly woody aroma<sup>37</sup>.

However, climate dictates the precise ratio of these volatiles. Principal component analyses (PCA) indicate that coriander grown in tropical or subtropical climates exhibits higher overall essential oil yields and maximum linalool concentrations (frequently exceeding 82%)<sup>37</sup>.

Conversely, coriander cultivated in cooler, temperate climates like Germany (e.g., the 'Thüringen' or 'Marino' cultivars) produces a slightly lower linalool percentage (averaging 65.73% to 71.4%) but compensates with significantly higher concentrations of secondary

terpenes such as  $\alpha$ -pinene (4.03% to 5.70%) and  $\gamma$ -terpinene (5.81% to 8.42%)<sup>37</sup>. This climatic shift results in a German coriander seed that presents a "mild-savoury" aroma with deeper, warmer citrus notes and a less aggressively soapy profile than its tropical counterparts—an ideal nuanced base for a rich butter masala<sup>36</sup>.

Cumin (*Cuminum cyminum*), on the other hand, is an obligate warm-season crop highly sensitive to frost<sup>44</sup>. As such, it is rarely cultivated successfully in northern Germany and must be imported from the eastern Mediterranean or South Asia<sup>44</sup>. Its primary volatile compound is cuminaldehyde, an aromatic aldehyde that delivers an earthy, warm, and highly pungent profile<sup>45</sup>.

## The Thermodynamics of Spice Blooming (*Tadka*)

To maximize the flavor impact of locally sourced coriander and cumin, the spices must undergo a process of thermal lipid extraction, known in Indian culinary science as *Tadka* or "blooming"<sup>46</sup>.

The critical flavor molecules in these spices—linalool in coriander and cuminaldehyde in cumin—are highly lipophilic (fat-soluble) and practically insoluble in water<sup>46</sup>. If raw or ground spices are dumped directly into a watery tomato base, their essential oils remain trapped within the fibrous plant matrix. Blooming requires briefly frying the ground or whole spices in a

high-heat lipid medium, such as homemade ghee, at temperatures between  $165^{\circ}\text{C}$  and  $170^{\circ}\text{C}$  for 30 to 60 seconds<sup>46</sup>.

At this elevated temperature, the intense kinetic energy rapidly volatilizes the essential oils, coaxing the hydrophobic flavor molecules out of the cellulose matrix and permanently dissolving them into the fat<sup>46</sup>. The ghee acts as a highly efficient organic solvent, capturing the complex aromas. Furthermore, this brief exposure to dry heat induces mild Maillard browning on the spice particles themselves, creating pyrazines that add a layer of roasted, nutty complexity<sup>46</sup>.

The temperature of the fat must then be immediately reduced by introducing wet ingredients (such as the onion or tomato base) to lower the thermal mass and prevent the delicate terpenes from thermally degrading into bitter ash<sup>46</sup>.

## The Thermodynamics of Cultured Ghee Production and Flavor Receptor Activation

The titular "Butter" in Chickpea Butter Masala is fundamentally a misnomer; the true depth and structural integrity of the dish rely heavily on clarified butter, or *ghee*. The use of homemade ghee is not merely a traditional preference but a biochemical necessity that profoundly alters

both the cooking process and human sensory perception.

## **Maillard Reactions and Oxidative Stability in *Sauerrahmbutter***

In Germany, high-quality butter is frequently available as *Sauerrahmbutter* (cultured or sour cream butter), which is fermented with lactic acid bacteria prior to churning<sup>50</sup>. This fermentation yields diacetyl, a highly volatile compound that imparts a profound, complex, and intensely "buttery" aroma not found in standard sweet cream butter<sup>50</sup>.

To convert this cultured butter into ghee, the emulsion of butterfat, water (roughly 16-18%), and milk proteins (casein and whey) must be thermally fractured. The butter is slowly heated until the water entirely evaporates<sup>52</sup>. Once the water is driven off, the temperature of the fat rapidly

ascends beyond the  $100^{\circ}\text{C}$  boiling point of water, reaching approximately  $120^{\circ}\text{C}$  to  $130^{\circ}\text{C}$  ( $248^{\circ}\text{F}$  to  $266^{\circ}\text{F}$ )<sup>52</sup>.

At this critical thermal threshold, the residual lactose sugars and milk proteins undergo the Maillard reaction, browning at the bottom of the pan<sup>52</sup>. This thermal decomposition generates a host of new flavor compounds, imparting a nutty, caramelized depth to the fat that standard clarified butter (which is filtered before browning occurs) completely lacks<sup>52</sup>. Fluorescence spectroscopy reveals that ghee extracted via the boiling of milk butter or milk skin (as opposed to direct cream extraction) preserves high concentrations of conjugated linoleic acid (CLA) and

vitamins A, D, E, and K<sup>55</sup>. Furthermore, clarifying ghee at  $120^{\circ}\text{C}$  for 15 minutes has been shown to reduce oxidation during storage (as quantified by Thiobarbituric acid reactive substances, or TBARS), enhancing shelf life while preserving sensory quality<sup>53</sup>. The caramelized milk solids are ultimately strained out, leaving pure, shelf-stable, anhydrous milk fat<sup>52</sup>.

## **Sensory Perception: CD36 Receptors, TRPV1, and Retronasal Olfaction**

The heavy use of ghee in the Makhani gravy serves as the ultimate delivery vehicle for flavor, acting upon human neurobiology through multiple integrated pathways.

Firstly, because ghee is roughly 99% pure milk fat, it acts as a superior lipophilic solvent for the molecules extracted during the spice blooming phase (linalool, cuminaldehyde, and capsaicin

from chili powder)<sup>50</sup>. As butter melts at roughly  $32^{\circ}\text{C}$  ( $90^{\circ}\text{F}$ )—just below human body temperature—it coats the palate with a slow-release flavor film that prevents these volatile compounds from immediately washing away with saliva<sup>50</sup>.

Secondly, as the fat coats the tongue, it activates the CD36 scavenger receptor, a specialized glycoprotein located in the taste buds that detects long-chain fatty acids<sup>57</sup>. The activation of CD36 triggers the brain's reward centers (the striatum and nucleus accumbens), flooding the system with dopamine and endorphins, signaling caloric density and inducing a profound sense of culinary pleasure<sup>50</sup>.

Simultaneously, the capsaicin dissolved in the ghee binds to TRPV1 (Transient Receptor Potential Vanilloid 1) receptors on the tongue<sup>57</sup>. TRPV1 is a thermoreceptor that normally

detects scalding heat (above  $43^{\circ}C$ )<sup>60</sup>. Capsaicin chemically tricks the receptor into firing, causing the brain to perceive a burning sensation<sup>57</sup>. The brain responds to this "benign masochism" by releasing additional endorphins to block the pain, creating the characteristic "chili high"<sup>60</sup>.

Finally, the warmth of the mouth volatilizes the lipid-bound spices, propelling them up the nasopharynx into the olfactory epithelium<sup>57</sup>. This process, known as retronasal olfaction, is responsible for the vast majority of what humans perceive as complex "flavor" (as opposed to basic orthonasal smelling)<sup>58</sup>. The heavy fat content of the ghee increases the viscosity of the bolus, which slows the release of these volatiles, ensuring the prolonged, lingering finish that characterizes a masterfully prepared Butter Masala<sup>50</sup>.

| Sensory Pathway         | Activating Compound                            | Physiological Response / Outcome                                                                  |
|-------------------------|------------------------------------------------|---------------------------------------------------------------------------------------------------|
| CD36 Scavenger Receptor | Long-chain fatty acids (Ghee)                  | Triggers striatum/nucleus accumbens; releases dopamine and endorphins <sup>50</sup> .             |
| TRPV1 Thermoreceptor    | Capsaicin (Chili Powder)                       | Simulates > heat; triggers endorphin release ("chili high") <sup>57</sup> .                       |
| Retronasal Olfaction    | Volatilized Terpenes (Linalool, Cuminaldehyde) | Compounds travel via nasopharynx; fat viscosity ensures a prolonged flavor finish <sup>58</sup> . |

## Architecting the Makhani Emulsion: The *Bhunao* Technique and Cashew Rheology

The defining architectural element of Chickpea Butter Masala is the gravy itself—a velvety, highly stable emulsion of fat, water, and acidic fruit pulp. Constructing this sauce requires navigating culinary history and executing precise physical and thermodynamic techniques.

### The "No-Onion" Debate and Authentic Gravy Structure

Within the realm of Indian gastronomy, a fierce historical and culinary debate exists regarding the structural base of a true *Makhani* (butter) gravy versus a standard Tikka Masala or generic Brown Gravy<sup>63</sup>. Authentic Murgh Makhani, originating from the Moti Mahal restaurant in Old Delhi in the 1950s, was designed exclusively around a base of slow-cooked pureed tomatoes, heavy butter, cream, and *Kasuri Methi*<sup>65</sup>. It strictly eschews the use of onions<sup>63</sup>.

However, many British Indian Restaurant (BIR) bases and modern fast-casual adaptations utilize a 1:2 ratio of onions to tomatoes to add bulk, sweetness, and speed to the preparation, cutting the tartness of canned tomatoes and bypassing the need for long simmer times<sup>67</sup>. For an expert-level, focused Makhani sauce, the "no-onion" rule is paramount<sup>63</sup>. The gravy must rely entirely on the natural acidity and concentrated umami (glutamate) of slowly reduced tomatoes, balanced by the richness of dairy and nut pastes<sup>63</sup>.

## The Rheology of Cashew Protein Emulsification

To thicken the sauce and provide a stable structural bridge between the acidic tomato water and the heavy application of liquid ghee, a paste of soaked cashews is introduced<sup>72</sup>. Cashew kernels (*Anacardium occidentale* L.) are exceptionally rich in proteins, predominantly globulins like anacardin, alongside high levels of unsaturated fats<sup>74</sup>.

When blended into a micro-particulate paste and introduced to the heat of the gravy, these cashew proteins act as highly effective amphiphilic emulsifiers<sup>77</sup>. The proteins undergo thermal denaturation, unfolding to expose their hydrophobic segments to the lipid droplets (ghee) and their polar ionic groups to the aqueous tomato phase<sup>77</sup>. This drastically reduces the interfacial tension between the water and oil phases. The proteins wrap the fat globules in a protective viscoelastic film that prevents coalescence, flocculation, and phase separation, even under high heat<sup>77</sup>.

Furthermore, cashew proteins exhibit excellent water-holding capacity (up to 2.42 g water/g protein) and high macro-viscosity indices<sup>77</sup>. They physically impede the movement of water molecules within the continuous phase, creating a pseudoplastic behavior that yields the characteristic "liquid silk" texture of a premium Makhani<sup>63</sup>. Crucially, the cashew proteins also act as a biochemical buffer against the high citric acid content of the tomatoes, preventing the dairy proteins (introduced later via heavy cream) from rapidly denaturing, curdling, and ruining the visual appeal and mouthfeel of the emulsion<sup>71</sup>.

## The *Bhunao* Technique: Kinetic Reduction and Oil Separation

The physical execution of the gravy relies on a classical Indian culinary technique known as *bhunao* (slow roasting and sautéing)<sup>71</sup>.

Once the tomato puree, cashew paste, and bloomed spices are combined, the mixture is subjected to prolonged, active simmering (a minimum of 40 minutes for authentic preparations)<sup>66</sup>. The primary objective of the *bhunao* stage is massive water evaporation<sup>64</sup>. As the water content drops, the specific heat capacity of the mixture changes, and the temperature of the sauce is allowed to climb beyond the boiling point of water ( $100^{\circ}\text{C}$ )<sup>71</sup>. This enters the thermal range necessary to trigger localized caramelization of the tomato sugars and further Maillard browning of the cashew proteins<sup>71</sup>. This sustained heat concentrates the glutamates in the tomatoes, exponentially increasing the savory depth of the sauce<sup>71</sup>.

The visual and thermodynamic indicator that the *bhunao* process is complete is the phenomenon of oil separation (often referred to in culinary vernacular as cooking "until the oil separates")<sup>68</sup>. Because the continuous aqueous phase of the emulsion has been largely evaporated away, the emulsion reaches a critical saturation point and temporarily breaks<sup>68</sup>. A

glossy, deep-ochre layer of spiced ghee rises to the periphery of the pan<sup>68</sup>. This visible stream of oil provides empirical proof that the raw, watery, acidic edge of the tomatoes has been entirely cooked out and replaced with a concentrated, complex flavor base<sup>68</sup>.

Only after this definitive oil separation is achieved is the sauce rehydrated slightly with water or stock, returning it to a stable, velvety emulsion<sup>83</sup>. The highly tenderized, high-pressure-cooked chickpeas—now completely devoid of RFOs and featuring gelatinized starch—are then folded into the matrix, allowing them to absorb the fat-soluble flavors without structural degradation.

## Finishing Dynamics: *Kasuri Methi* and the Sotolon

### Matrix

The defining aromatic signature of any authentic Makhani dish is *Kasuri Methi*, the dried leaves of the fenugreek plant (*Trigonella foenum-graecum*)<sup>65</sup>. Grown across India as a winter crop, fenugreek leaves are naturally dried, preserving a complex phytochemical profile rich in flavonoids, galactomannans, and steroidal saponins (diosgenin)<sup>85</sup>. However, the primary volatile compound responsible for its unmistakable, slightly bitter, herbaceous, and maple-syrup-like aroma is *sotolon* (3-hydroxy-4,5-dimethyl-2(5H)-furanone)<sup>51</sup>.

Unlike the highly volatile linalool found in green cardamom or coriander, which flashes off and evaporates quickly under sustained heat, *sotolon* exhibits profound thermal stability<sup>51</sup>. Despite this stability, to preserve its delicate herbaceous top notes and prevent bitterness, *Kasuri Methi* is never subjected to the initial high-heat *tadka*<sup>51</sup>. Instead, the dried leaves are crushed vigorously between the palms—a mechanical action that physically ruptures the dried cell walls to release the essential oils—and sprinkled over the dish during the final minutes of simmering<sup>51</sup>. This allows the *sotolon* to infuse seamlessly into the lipid-rich sauce, balancing the richness of the butter and cream with a necessary aromatic astringency<sup>51</sup>.

The dish is finally removed from the heat and finished with a heavy swirl of cold-pressed double cream (the cold temperature aiding in final emulsification) and a final dollop of butter for a glossy sheen, ensuring the sauce holds its velvet grip on the palate<sup>51</sup>.

### Conclusion

The creation of a flawless Chickpea Butter Masala is a triumph of applied physical chemistry, localized agronomic adaptation, and rigorous molecular gastronomy. Cultivating the primary ingredients within the temperate constraints of the Berlin-Brandenburg region necessitates a deep understanding of soil pedology, thermal kinetics, and specific vine-curing harvest mechanics to prevent physiological defects like the Hard-To-Cook phenomenon. By confronting the chemical realities of hard municipal water with precise alkaline interventions using sodium bicarbonate, the cellular architecture of the chickpea is dismantled. This process hydrolyzes hemicellulose, diffuses flatulence-causing oligosaccharides, and allows high-pressure thermal processing to achieve complete starch gelatinization and exceptional tenderness.

Furthermore, the integration of locally adapted European coriander, bloomed in homemade, Maillard-browned cultured ghee, maximizes the extraction of lipophilic terpenes. This highly calibrated lipid delivery system acts directly upon human neurological reward systems, simultaneously triggering CD36 fatty acid receptors and TRPV1 thermoreceptors while

facilitating retronasal olfaction. Finally, by mastering the rheological stabilization provided by cashew globulins and executing the traditional *bhunao* technique to achieve kinetic water reduction and oil separation, the resulting emulsion balances tomato acidity and achieves a level of textural velvet and aromatic complexity that elevates plant-based gastronomy to its highest technical standard.

## Works cited

1. 29 Garbanzo And Black Bean Agronomy.pdf
2. (PDF) Effect of soaking and cooking on nutritional quality and safety, [https://www.researchgate.net/publication/242335497\\_Effect\\_of\\_soaking\\_and\\_cooking\\_on\\_nutritional\\_quality\\_and\\_safety\\_of\\_legumes](https://www.researchgate.net/publication/242335497_Effect_of_soaking_and_cooking_on_nutritional_quality_and_safety_of_legumes)
3. Techno-Functional and In Vitro Digestibility Properties of Gluten, <https://pmc.ncbi.nlm.nih.gov/articles/PMC10416885/>
4. Protein and microstructure evaluation of harder-to-cook and easy-to-cook grains from different kidney bean accessions, [https://www.researchgate.net/publication/312399248\\_Protein\\_and\\_microstructure\\_evaluation\\_of\\_harder-to-cook\\_and\\_easy-to-cook\\_grains\\_from\\_different\\_kidney\\_bean\\_accessions](https://www.researchgate.net/publication/312399248_Protein_and_microstructure_evaluation_of_harder-to-cook_and_easy-to-cook_grains_from_different_kidney_bean_accessions)
5. Using Dried Chickpeas and Baking Soda for Perfect Beans, <https://countrylifefoods.com/blogs/beans-and-legumes/using-dried-chickpeas-and-baking-soda-for-perfect-beans>
6. Cooking Dried Chickpeas With Baking Soda for Perfect Results, <https://countrylifefoods.com/blogs/beans-and-legumes/cooking-dried-chickpeas-with-baking-soda-for-perfect-results>
7. Tap Water in Berlin: Quality, Hardness, and Filtration, <https://littlebigproject.de/tap-water-in-berlin-quality-hardness-and-filtration>
8. Valorization of Fibrous Plant-Based Food Waste as Biosorbents for, <https://pmc.ncbi.nlm.nih.gov/articles/PMC10221818/>
9. Chemistry-and-Uses-of-Pectin-A-Review.pdf - ResearchGate, [https://www.researchgate.net/profile/Avtar-Handa/publication/14145382\\_Chemistry\\_and\\_Uses\\_of\\_Pectin\\_-\\_A\\_Review/links/00b49534550d98dc4d000000/Chemistry-and-Uses-of-Pectin-A-Review.pdf](https://www.researchgate.net/profile/Avtar-Handa/publication/14145382_Chemistry_and_Uses_of_Pectin_-_A_Review/links/00b49534550d98dc4d000000/Chemistry-and-Uses-of-Pectin-A-Review.pdf)
10. Tips for Fixing Dried Chickpeas Not Softening, <https://countrylifefoods.com/blogs/beans-and-legumes/tips-for-fixing-dried-chickpeas-not-softening>
11. How To Cook Chickpeas (Ultimate Guide) - Forks and Foliage, <https://forksandfoliage.com/how-to-cook-chickpeas/>
12. Why (And How) You Should Add Baking Soda To Your Chickpeas, [https://www.huffingtonpost.co.uk/entry/chickpeas-softer-baking-soda\\_uk\\_6a7dba69e4b08acce259bc6](https://www.huffingtonpost.co.uk/entry/chickpeas-softer-baking-soda_uk_6a7dba69e4b08acce259bc6)
13. Effect of calcium/sodium addition on rice starch-chickpea protein, <https://pmc.ncbi.nlm.nih.gov/articles/PMC12143718/>
14. The Ultimate Guide to Cooking Dried Chickpeas | Feasting At Home, <https://www.feastingathome.com/how-to-cook-chickpeas/>
15. Soaking Grains Exploration: What is the pH of your Favorite Soaking,

- <https://www.kitchenstewardship.com/soaking-grains-exploration-what-is-the-ph-of-your-favorite-soaking-medium/>
16. Effect of soaking and cooking on dietary fibre components of ... - PMC, <https://pmc.ncbi.nlm.nih.gov/articles/PMC3602558/>
  17. (PDF) Effect of soaking and cooking on dietary fibre components of, [https://www.researchgate.net/publication/230744248\\_Effect\\_of\\_soaking\\_and\\_cooking\\_on\\_dietary\\_fibre\\_components\\_of\\_different\\_type\\_of\\_chickpea\\_genotypes](https://www.researchgate.net/publication/230744248_Effect_of_soaking_and_cooking_on_dietary_fibre_components_of_different_type_of_chickpea_genotypes)
  18. When making hummus, what is the purpose of boiling chickpeas in, <https://www.quora.com/When-making-hummus-what-is-the-purpose-of-boiling-chickpeas-in-water-with-baking-soda>
  19. Biotechnological Modulation of Legumes via Fermentation - MDPI, <https://www.mdpi.com/2304-8158/15/14/2483>
  20. Present status on removal of raffinose family oligosaccharides, [https://cifs.agriculturejournals.cz/artkey/cjf-201903-0001\\_present-status-on-removal-of-raffinose-family-oligosaccharides-a-review.php](https://cifs.agriculturejournals.cz/artkey/cjf-201903-0001_present-status-on-removal-of-raffinose-family-oligosaccharides-a-review.php)
  21. Evaluation of two methods to reduce legume-related flatulence, <https://d-nb.info/121334915X/34>
  22. (PDF) Effect of Chemical Soaking, Toasting and Crude  $\alpha$ , [https://www.researchgate.net/publication/304033907\\_Effect\\_of\\_Chemical\\_Soaking\\_Toasting\\_and\\_Crude\\_alpha-Galactosidase\\_Enzyme\\_Treatment\\_on\\_the\\_Oligosaccharide\\_Content\\_of\\_Red\\_Gram\\_Flour\\_Effect\\_of\\_Chemical\\_Soaking\\_Toasting\\_and\\_Crude](https://www.researchgate.net/publication/304033907_Effect_of_Chemical_Soaking_Toasting_and_Crude_alpha-Galactosidase_Enzyme_Treatment_on_the_Oligosaccharide_Content_of_Red_Gram_Flour_Effect_of_Chemical_Soaking_Toasting_and_Crude)
  23. Hydrolysis and diffusion of raffinose oligosaccharides ... - PubMed, <https://pubmed.ncbi.nlm.nih.gov/39059925/>
  24. Reduction in soaking time and anti-nutritional factors by high ... - PMC, <https://pmc.ncbi.nlm.nih.gov/articles/PMC7270391/>
  25. Instant Pot Chickpeas (Soaked and No Soak) - Know Your Produce, <https://www.knowyourproduce.com/instant-pot-chickpeas/>
  26. Compositional, morphological, and physicochemical properties of, <https://pmc.ncbi.nlm.nih.gov/articles/PMC6694421/>
  27. (PDF) Extraction, characterization, physicochemical and rheological, [https://www.researchgate.net/publication/337488264\\_Extraction\\_characterization\\_physicochemical\\_and\\_rheological\\_properties\\_of\\_two\\_different\\_varieties\\_of\\_chickpea\\_starch](https://www.researchgate.net/publication/337488264_Extraction_characterization_physicochemical_and_rheological_properties_of_two_different_varieties_of_chickpea_starch)
  28. Comparative study on chemical, functional and pasting properties of, <https://www.cabidigitallibrary.org/doi/pdf/10.5555/20153167141>
  29. CHICKPEAS Ingredients and Applications - USA Pulses EU, <https://usapulseseu.org/wp-content/uploads/2025/04/Processing-chickpeas.pdf>
  30. Ultrasound-Assisted Soaking and Solution Effects on the Anti ... - PMC, <https://pmc.ncbi.nlm.nih.gov/articles/PMC11973125/>
  31. Spice Village - Indian Online Grocery Store in Germany | Berlin, <https://www.spicevillage.eu/>
  32. Where can I buy fresh coriander/ cilantro in kreuzberg? : r/berlin, [https://www.reddit.com/r/berlin/comments/1fnx5c/where\\_can\\_i\\_buy\\_fresh\\_coriander\\_cilantro\\_in/](https://www.reddit.com/r/berlin/comments/1fnx5c/where_can_i_buy_fresh_coriander_cilantro_in/)

33. Namma Markt: No.1 Indian Grocery Store In Berlin, Germany,  
<https://www.nammamarkt.com/blogs/blogs/no-1-indian-grocery-store-in-berlin-germany>
34. AnuHita Groceries: Indian Grocery Store in Berlin, <https://anuhitagroceries.de/>
35. Coriander Powder Manufacturers in Germany - Natural Spices,  
<https://www.naturalspicesllp.com/coriander-powder-in-germany.php>
36. Buy Coriander Seeds – Churfranken Region | Altes Gewürzamt,  
<https://altesgewuerzamt.de/en/products/korianderkorner-churfranken>
37. Variation in essential oil composition of coriander (Coriandrum,  
[https://www.researchgate.net/publication/319018145\\_Variation\\_in\\_essential\\_oil\\_composition\\_of\\_coriander\\_Coriandrum\\_sativumL\\_varieties\\_cultivated\\_in\\_two\\_different\\_ecologies](https://www.researchgate.net/publication/319018145_Variation_in_essential_oil_composition_of_coriander_Coriandrum_sativumL_varieties_cultivated_in_two_different_ecologies)
38. Do Climate Conditions Affect the Quality of the Apiaceae Fruits,  
<https://www.mdpi.com/2311-7524/10/6/577>
39. GC-MS Analysis of the Composition of the Essential Oil from ... - PMC,  
<https://pmc.ncbi.nlm.nih.gov/articles/PMC6017652/>
40. Climate Zone of Geographical Origin Associations with Essential Oil,  
<https://pmc.ncbi.nlm.nih.gov/articles/PMC13257553/>
41. change in essential oil yield, content and composition of coriander,  
[https://rjas.ro/download/paper\\_version.paper\\_file.9fe9bb364df1ae50.TUFOSEFSVC1jb3JpYW5kZXlucGRm.pdf](https://rjas.ro/download/paper_version.paper_file.9fe9bb364df1ae50.TUFOSEFSVC1jb3JpYW5kZXlucGRm.pdf)
42. Mathematical approach used for the assessment of foliar application,  
<http://lib.au-plovdiv.bg:8081/SPP/np010118/F0010118.pdf>
43. Organic coriander seeds | ground - Biova GmbH,  
<https://biova.de/en/organic-coriander-seeds-ground/9832>
44. Cumin - Grokipedia, <https://grokipedia.com/page/Cumin>
45. Handbook of Herbs and Spices [Volume 2, 1 ed.] 9780849325359,  
<https://dokumen.pub/handbook-of-herbs-and-spices-volume-2-1nbsped-9780849325359-9781855737211-9781855738355-0849325358-1855737213-9780203023945.html>
46. How to Use Spices Chart: Flavor Any Dish Easily - Villorya Organics,  
<https://www.villorya.com/blogs/how-to-use-spices-chart>
47. Cumin: The Flavour of Indian Cuisines-History, Cultivation and Uses,  
[https://www.academia.edu/39875985/Cumin\\_The\\_Flavour\\_of\\_Indian\\_Cuisines\\_History\\_Cultivation\\_and\\_Uses](https://www.academia.edu/39875985/Cumin_The_Flavour_of_Indian_Cuisines_History_Cultivation_and_Uses)
48. List of Indian spices - Grokipedia,  
[https://grokipedia.com/page/List\\_of\\_Indian\\_spices](https://grokipedia.com/page/List_of_Indian_spices)
49. (PDF) ROLE OF INDIAN SPICES IN INDIAN HISTORY - ResearchGate,  
[https://www.researchgate.net/publication/365451144\\_ROLE\\_OF\\_INDIAN\\_SPICES\\_IN\\_INDIAN\\_HISTORY](https://www.researchgate.net/publication/365451144_ROLE_OF_INDIAN_SPICES_IN_INDIAN_HISTORY)
50. Why does butter make food taste better? - Quora,  
<https://www.quora.com/Why-does-butter-make-food-taste-better>
51. Dal Makhani Recipe (Authentic Punjabi Black Lentils),  
<https://cardamomnectar.com/dal-makhani-recipe>
52. How to Make Ghee (Step-by-Step Guide) - Jessica Gavin,

- <https://www.jessicagavin.com/how-to-make-ghee/>
53. Oxidative stability of ghee clarified at various time - ResearchGate,  
[https://www.researchgate.net/publication/388389093\\_Oxidative\\_stability\\_of\\_ghee\\_clarified\\_at\\_various\\_time\\_Temperature\\_combinations](https://www.researchgate.net/publication/388389093_Oxidative_stability_of_ghee_clarified_at_various_time_Temperature_combinations)
  54. Recent innovations in functionality and shelf life enhancement of,  
<https://pmc.ncbi.nlm.nih.gov/articles/PMC9813307/>
  55. Characterization of Desi Ghee Extracted by Different Methods Using,  
<https://pubmed.ncbi.nlm.nih.gov/31758370/>
  56. Studying heating effects on desi ghee obtained from buffalo milk,  
<https://pmc.ncbi.nlm.nih.gov/articles/PMC5947909/>
  57. The Science of Cooking: Biology & Chemistry of Food - studylib.net,  
<https://studylib.net/doc/26282255/the-science-of-cooking--understanding-the-biology-and-chemistry...>
  58. Molecular Gastronomy: A New Emerging Scientific Discipline,  
<https://pubs.acs.org/chcreay/article/110/4/2313/247070/Molecular-Gastronomy-A-New-Emerging-Scientific>
  59. Extraoral Taste Receptor Discovery: New Light on Ayurvedic ... - PMC,  
<https://pmc.ncbi.nlm.nih.gov/articles/PMC5469997/>
  60. China 7 Irresistible Hot Garlic Sauces for 2025: The Ultimate Guide,  
<https://www.limintiaoliao.com/7-irresistible-hot-garlic-sauces-for-2025-the-ultimate-guide-to-hot-garlic-butter-sauce-hot-garlic-chili-sauce-hot-pepper-garlic-sauce/>
  61. Molecular Gastronomy: A New Emerging Scientific Discipline - PMC,  
<https://pmc.ncbi.nlm.nih.gov/articles/PMC2855180/>
  62. Food Chemistry and Safety Guide | PDF | Periodic Table - Scribd,  
<https://www.scribd.com/document/948987668/Sharon-Croxford-Emma-Stirling-Understanding-the-Science-of-Food-From-Molecules-to-Mouthfeel-2017-Allen-Unwin-Libgen-li>
  63. A Connoisseur's Guide to Authentic Butter Chicken - Copper Chimney,  
<https://www.copperchimney.com.sg/post/the-velvet-revolution-a-connoisseur-s-guide-to-authentic-butter-chicken>
  64. Can someone explain curry differences like I'm 5? - Reddit,  
[https://www.reddit.com/r/IndianFood/comments/1krwxoz/can\\_someone\\_explain\\_curry\\_differences\\_like\\_im\\_5/](https://www.reddit.com/r/IndianFood/comments/1krwxoz/can_someone_explain_curry_differences_like_im_5/)
  65. Chicken Makhani vs Butter Chicken: Are They the Same?,  
<https://www.tedcoeducation.com/is-chicken-makhani-the-same-as-butter-chicken>
  66. Butter Chicken vs Chicken Tikka Masala: Key Differences,  
<https://sherepanjab.au/blogs/news/butter-chicken-vs-chicken-tikka-masala-whats-the-difference-and-which-is-better>
  67. proportion of onions to tomatoes in north indian dishes like paneer,  
[https://www.reddit.com/r/IndianFood/comments/1htq8o0/proportion\\_of\\_onions\\_to\\_tomatoes\\_in\\_north\\_indian/](https://www.reddit.com/r/IndianFood/comments/1htq8o0/proportion_of_onions_to_tomatoes_in_north_indian/)
  68. Cook until oil separates - Indian Basics - The Magic Saucepan,  
<https://themagicsaucepan.com/basics/until-oil-separates-cook-until-oil>
  69. Why does BIR base gravy use way more Ingredients than ... - Reddit,  
[https://www.reddit.com/r/IndianFood/comments/vag3k1/why\\_does\\_bir\\_base\\_grav](https://www.reddit.com/r/IndianFood/comments/vag3k1/why_does_bir_base_grav)

[y\\_use\\_way\\_more\\_ingredients/](#)

70. Makhani Sauce - Pure Curry, <https://www.purecurry.com/makhani-sauce/>
71. 1203010496.pdf - Balbharati, <https://books.ebalbharati.in/pdfs/1203010496.pdf>
72. Easy Makhani Sauce (Makhani Gravy) | Cook Click N Devour!!!, <https://www.cookclickndevour.com/makhani-sauce-makhani-gravy/>
73. Makhani Sauce Master Gravy Recipe + Tomato & Onion ... - YouTube, <https://www.youtube.com/watch?v=-ql6XFUpmmY>
74. Production Technology of Fruit and Plantation Crops agrimoon.com, <https://agrimoon.com/wp-content/uploads/Production-Technology-of-Fruit-and-Plantation-Crops.pdf>
75. Molecular and Functional Properties of Protein Fractions and Isolate, <https://pmc.ncbi.nlm.nih.gov/articles/PMC6016967/>
76. Functional properties of protein concentrates and isolates produced, [https://www.researchgate.net/publication/223775259\\_Functional\\_properties\\_of\\_protein\\_concentrates\\_and\\_isolates\\_produced\\_from\\_cashew\\_Anacardium\\_Ocidentale\\_L\\_nut](https://www.researchgate.net/publication/223775259_Functional_properties_of_protein_concentrates_and_isolates_produced_from_cashew_Anacardium_Ocidentale_L_nut)
77. Nut Proteins as Plant-Based Ingredients - MDPI, <https://www.mdpi.com/2227-9717/12/8/1742>
78. The Emulsifying Properties, In Vitro Digestion Characteristics and, <https://pmc.ncbi.nlm.nih.gov/articles/PMC10670896/>
79. (PDF) Effect of pH on protein extraction from sour cherry kernels and, [https://www.researchgate.net/publication/332701416\\_Effect\\_of\\_pH\\_on\\_protein\\_extraction\\_from\\_sour\\_cherry\\_kernels\\_and\\_functional\\_properties\\_of\\_resulting\\_protein\\_concentrate](https://www.researchgate.net/publication/332701416_Effect_of_pH_on_protein_extraction_from_sour_cherry_kernels_and_functional_properties_of_resulting_protein_concentrate)
80. Characterization of the physicochemical, thermal and rheological, <https://pmc.ncbi.nlm.nih.gov/articles/PMC9532777/>
81. Trainee Chef | PDF | Hotel | Soup - Scribd, <https://www.scribd.com/document/1000195528/Trainee-Chef>
82. The Ultimate Authentic Butter Chicken Masala Recipe: A Culinary, <https://pathter.com/butter-chicken-masala-recipe/>
83. Vegan Makhani Sauce - Food Kalakaar, <https://foodkalakaar.com/2020/05/01/vegan-makhani-sauce/>
84. Traditional matar and makhani recipes calling for a crazy amount of, [https://www.reddit.com/r/IndianFood/comments/kzgoq3/traditional\\_matar\\_and\\_makhani\\_recipes\\_calling\\_for/](https://www.reddit.com/r/IndianFood/comments/kzgoq3/traditional_matar_and_makhani_recipes_calling_for/)
85. Kasuri Methi (Dried Fenugreek) from India - Table Indienne, <https://www.table-indienne.fr/en/products/kasuri-methi-dried-fenugreek>
86. Phytotherapeutic, Nutraceutical, Medicinal, and Forage Properties of, [https://www.researchgate.net/publication/384625427\\_Phytotherapeutic\\_Nutraceutical\\_Medicinal\\_and\\_Forage\\_Properties\\_of\\_Fenugreek\\_Trigonella\\_foenum-graecum\\_L\\_A\\_Comprehensive\\_Review](https://www.researchgate.net/publication/384625427_Phytotherapeutic_Nutraceutical_Medicinal_and_Forage_Properties_of_Fenugreek_Trigonella_foenum-graecum_L_A_Comprehensive_Review)
87. Herbs & Spices of The Word | PDF | Curry | Thai Cuisine - Scribd, <https://www.scribd.com/document/595052550/HERBS-SPICES-OF-THE-WORD>
88. A Review on the Functional Properties, Nutritional Content, <https://www.cabidigitallibrary.org/doi/pdf/10.5555/20133129457>