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MODERN MILITARY-TACTICAL INTEGRATION OF LOCAL PHYTOCHEMICAL RESOURCES: NANOTECHNOLOGICAL MODIFICATION AND THE PROSPECTS OF AUTONOMOUS PRECISION SYSTEMS

(The Case of Capsicum)

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Abstract

This article investigates the historical application, chemical-biological characteristics, and advanced technological and nanotechnological prospects of active alkaloids within local agro-industrial raw materials - hot pepper (Capsicum) - in the military and law enforcement spheres, as well as their deployment in the contemporary Multi-Domain Operations theater. The mechanisms through which capsaicin, the active chemical agent in pepper, impacts human neuro-receptors and cognitive stability are analyzed from a biological perspective. Furthermore, the paper provides a scientific substantiation

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for the strategic-tactical prospects of extracting the Oleoresin Capsicum (OC) phytochemical agent from local cultivars such as Margilan-333, microencapsulating it, and integrating it into drone ecosystems within the defense industry framework of the Republic of Uzbekistan under conditions of global logistical crises.

Keywords: Phytochemical defense, Capsicum, microencapsulation, nano-carriers, UAV tactics, cyber-physical barriers, green defense, Oleoresin Capsicum, TRPV1 modulation, non-lethal weapons, cognitive dispersion.

Introduction

Under conditions of dynamic changes in the international and regional security architecture, the escalation of geopolitical confrontations, and the weakening of transnational supply chains, the reliance of defense industry complexes on local raw materials and phytochemical resources has emerged as a fundamental prerequisite for national security. A retrospective analysis of military history reveals that humanity has continuously engineered novel weapon systems to ensure survival, territorial integrity, and strategic dominance. The evolutionary chain that initiated with stone knives, spears, and bows eventually led to firearms through the discovery of gunpowder, and subsequently culminated in catastrophic weapons of mass destruction (nuclear, chemical, and biological weapons). However, contemporary hybrid conflicts of the twenty-first century task the armed forces with deploying high-precision non-lethal weapon systems capable of neutralizing the enemy's live forces without compromising civilian hostages or critical infrastructures, operating alongside conventional lethal assets.

“Nanotechnological modification and the prospects of autonomous precision systems” represents a strategic concept emerging at the convergence of modern military engineering, biotechnology, and artificial intelligence. It delineates the vector of refining and perfecting defensive agents at the molecular level and

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delivering them to targets with ultra-high accuracy (precision) via robotized intelligent platforms.

In simpler terms, this concept refers to a technology that renders traditional tools – such as the phytochemical pepper extract analyzed in our study above – resilient to environmental and atmospheric anomalies using nanotechnological structures, subsequently deploying them point-by-point against the enemy utilizing autonomous drones, thereby bypassing human intervention entirely.

The operational essence and prospective significance of this paradigm are anchored upon two fundamental pillars:

1. Nanotechnological Modification (Protection and Control at the Molecular Level). Classical chemical compounds or irritants rapidly lose their quantitative potency or disperse in unintended directions under open-air conditions (such as wind, rain, or high thermal baselines).

Nanotechnological modification fundamentally resolves this structural limitation:

- **Microencapsulation:** The active phytochemical agent (capsaicin) is encapsulated within nano-particles or specialized polymer matrix shells in a stable, dormant state.

- **Controlled Release:** The substance does not undergo random atmospheric dispersion. It ruptures its polymer encapsulation and triggers with maximum concentration only upon a kinetic impact with the target (at the moment of mechanical impact) or when interacting with the thermal parameters of the human body.

2. Autonomous Precision Systems (High Accuracy Free from the Human Factor). This component serves as the delivery architecture for transferring these modified intelligent agents into the combat zone without exposing the soldier's life to direct hazards:

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- **Autonomy:** Controlled by artificial intelligence and interacting via decentralized networks, a swarm of drones (UAV swarms) executes operational commands independently, completely free from human intervention.

- **Precision (Ultra-Accuracy):** The defensive agent is deployed not en masse, but targeted pinpointedly to the precise coordinates of the enemy's footprint (for instance, explicitly inside a structural room where hostile actors are barricaded). This mechanism inflicts zero damage on the surrounding civilian populace or infrastructure.

The ultimate objective of this advanced technological vector is to pivot warfare tactics away from linear, destructive methodologies (mass destruction) and transition toward the "**zero collateral damage**" paradigm. The operational capacity of the adversary is completely restricted without the deployment of kinetic force (bullets or bombs) by pinpointedly paralyzing their sensory networks via nanotechnological gels.

In this context, hot pepper (*Capsicum*) cultivars widely cultivated within the agricultural sector are not merely a conventional source of irritants, but represent a strategic phytochemical agent that can be effectively weaponized through the convergence of modern biotechnology, materials science, and cyber-physical systems. Under the constraints imposed by the highly toxic nature, environmental degradation, and international-legal restrictions of classic synthetic combat gases (such as CS and CN gases), capsaicin – the natural alkaloid found within pepper – fully satisfies the paradigms of "**Green Defense**" due to its inherent biodegradable properties. Deeply processing local raw materials to manufacture protective and tactical equipment for military and specialized units facilitates the strategic and economic optimization of the national defense budget.

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Historical Retrospective of Pepper Deployment in the Military Sphere.

An examination of the historical retrospective of pepper's application in the military domain reveals that utilizing hot pepper for tactical and defensive purposes began successfully in ancient asymmetric warfare, centuries prior to the inception of industrial chemical synthesis and laboratory manufacturing. According to archaeological and historical records, hot pepper was deployed as a tactical object by indigenous populations as early as 300 BC. This historical reality is empirically substantiated by biochemical analyses of phytochemical residues recovered from ceramic vessels and ritual stones discovered in ancient settlements across southwestern Mexico and Ecuador (specifically the Loma Alta and Real Alto sites).

Tactics of Ancient Civilizations of the American Continent: The indigenous populations (including the Incas and Mayans) deployed specialized phytochemical weapon scenarios in their asymmetrical struggles against the armored and firearm-equipped infantries of the Spanish conquistadors. The most prominent historical manifestation of this tactic occurred in 1532 during a decisive engagement along the banks of the Orinoco River. Operating under coordinated tactical commands, the indigenous forces cast massive quantities of dried hot pepper fruits onto pre-arranged burning embers. Because the wind vectors were calculated with absolute precision, the resulting hyper-acute and toxic smoke screen was carried directly into the defensive lines of the Spanish army. Blinded by the intense irritation of their ocular and respiratory systems, the conquistadors and their mounts were forced to abandon their weapons and retreat to the river to cleanse their eyes. This outcome completely shattered their tactical combat formation and secured a definitive victory for the indigenous forces.

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Ancient Eastern and Global Military Art: In ancient China and India, pulverized hot pepper powders were encased within specialized paper shells to be hurled at advancing forces or dispersed across distances using specialized mechanical blowpipes. This methodology functioned as a highly effective instrument for breaking the visual focus and situational awareness of the adversary (**cognitive dispersion**) during fortress wall defense operations and unanticipated tactical ambushes. Furthermore, military contingents operating under field conditions systematically applied hot pepper extracts along the defensive perimeters of their encampments and temporary barracks. This defensive measure successfully repelled apex predators and wild animals away from the camp footprint via its potent olfactory signature. Concurrently, integrating hot pepper into the dietary rations of soldiers deployed in sub-zero climates warmed their physiology internally, significantly elevating their metabolic baseline and operational alertness.

By the second half of the twentieth century, these empirical and historical methodologies were elevated to the status of standardized military-tactical assets through the advancements of chemical engineering.

Biochemical Profile and Sensory Neurobiology of Capsaicin. The military-tactical value of pepper is fundamentally determined by its constituent phenolic compound, the alkaloid capsaicin (chemical formula: $C_{18}H_{27}NO_3$). Capsaicin is an exceptionally stable, water-insoluble compound that exhibits high extraction efficiency in alcohols, hydrocarbons, and lipids.

Regarding its mechanism of action on the human organism, capsaicin operates precisely at the neuro-receptor level:

- **Activation of TRPV1 Receptors:** Capsaicin molecules enter into direct molecular bonding with Transient Receptor Potential Vanilloid 1 (TRPV1) ion channels (receptors) located within human mucous membranes (eyes, nose, respiratory tract) and the cutaneous layer. Under physiological baselines, these

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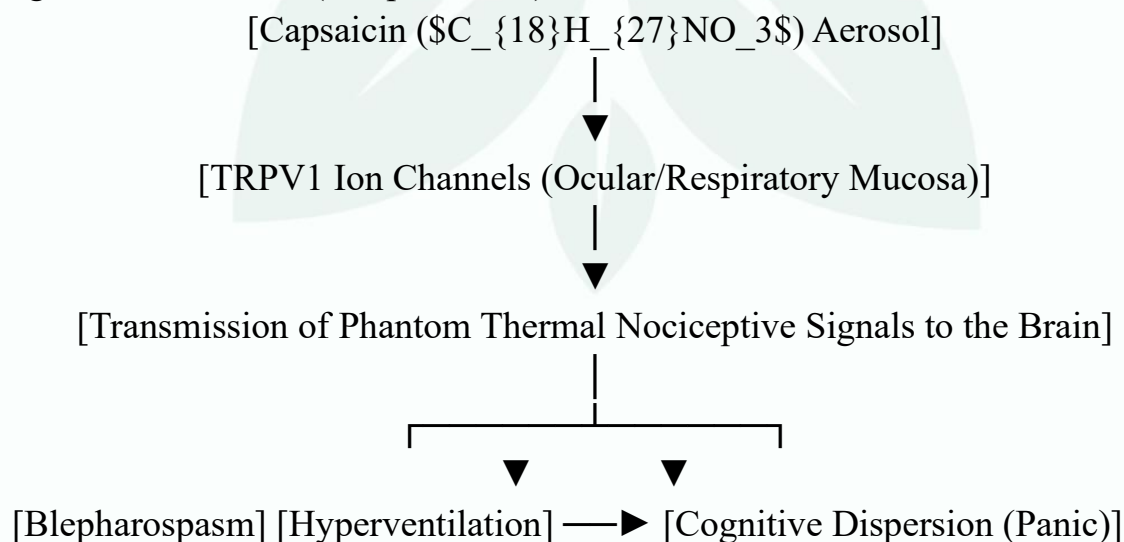
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receptors function to alert the organism against high temperatures (>43C) and thermal burns, thereby serving as primary mediators of thermal nociception.

- **Cognitive Diversion and Phantom Pain Homeostasis:** Upon interacting with TRPV1 receptors, capsaicin prompts the transmission of phantom nociceptive signals to the cerebral cortex via unmyelinated nerve fibers (C-fibers), falsely indicating that the organism is undergoing severe thermal combustion and overt tissue destruction. Consequently, despite the absolute absence of an actual thermal injury, the brain perceives the physiological state as an acute thermal catastrophe.

When a military service member or an offender falls within the operational envelope of a capsaicin aerosol, the following absolute physiological and cognitive constraints (incapacitation) manifest:



- **Blepharospasm:** Acute irritation of the ocular mucosa triggers a reflexive contraction of the eyelids, inducing complete and involuntary loss of visual capacity for a duration of 20–30 minutes. Irrigating the eyes with water fails to mitigate the effect; conversely, it exacerbates the severity of the reaction by facilitating the wider dispersion of capsaicin particles across the dermal surface.

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• **Dyspnea and Hyperventilation:** Inflammation of the upper respiratory tract initiates uncontrollable and severe coughing fits, laryngospasms, and rapid, shallow breathing (hyperventilation), which entirely collapses the subject's capacity for any active physical exertion.

• **Psychological Disorientation and Cognitive Dispersion:** The sudden onset of intense pain and functional blindness induces a high state of panic and acute operational disorientation within the subject. Consequently, the individual loses the capacity to manage tactical weaponry or maintain situational coordination.

The Role and Nanotechnological Evolution of the Oleoresin Capsicum (OC) Agent within Modern Non-Lethal Weapon Systems. When examining the contemporary architecture of non-lethal weapons, the Oleoresin Capsicum (OC) phytochemical agent – formulated on the basis of concentrated pepper extracts – is widely deployed within the arsenals of global militaries and specialized law enforcement units. The OC compound exhibits a series of tactical advantages over traditional synthetic lachrymatory gases (such as CS or CN). Synthetic agents often exhibit diminished efficacy against subjects with elevated pain thresholds, such as individuals undergoing acute psychological crises or under the influence of alcohol and narcotics. Conversely, because OC operates directly at the biological receptor level, it executes an absolute, reflexive blockage of the subject's ocular and respiratory pathways, irrespective of the underlying state of their central nervous system.

Within contemporary tactical scenarios, OC is utilized in two primary configurations:

1. Tactical Aerosols and Gels: Deployed as an operational tool for clearing enclosed structures or temporarily halting adversary movement during close-quarters combat by specialized units.

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2. Pneumatic Pepper-Ball Systems: High-precision delivery configurations discharged via specialized pneumatic weapons up to a distance of 20–30 meters. Upon kinetic impact with the target, the projectile ruptures, dispersing a highly concentrated cloud of particulate OC powder across the immediate radius.

Nanotechnological Modification: Microencapsulation. The primary operational limitation of conventional pepper sprays lies in their extreme vulnerability to meteorological variations, such as crosswinds, high ambient temperatures, and atmospheric precipitation. Contemporary military-chemical engineering resolves this architectural bottleneck through nanotechnological modification. Pure capsaicin molecules extracted from raw pepper are encapsulated within a shell of biodegradable polymers, such as poly(lactic-co-glycolic acid) (PLGA).

These polymeric nanocarriers isolate the active agent from environmental degradation and trigger a controlled release explicitly upon a mechanical impact with the target or when contacting the thermodynamic baseline of the human body. This advanced configuration preserves the payload concentration against atmospheric dispersion, increasing the efficiency of delivery to the adversary's TRPV1 receptors by up to 300%.

Autonomous Precision Systems and UAV Integration. The contemporary multi-domain theater of operations has rapidly transformed into a proving ground for unmanned aerial vehicles (UAVs) and autonomous robotized systems. Consequently, the next generation of phytochemical delivery vectors is being directly integrated into the architecture of unmanned aerial systems:

- **Tactical Phytochemical Drone Swarms (Phytochemical Dragon Swarms):** Autonomous swarms of miniature unmanned aerial vehicles (UAVs) managed by artificial intelligence infiltrate adversary fortifications or enclosed architectural

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structures. Operating as a decentralized, hive-like formation, these drones deploy microencapsulated particulate Oleoresin Capsicum (OC) powder aerosols via precision, point-source dispersion mechanisms instead of conventional kinetic explosives. This advanced payload integration empowers specialized units to neutralize, disorient, and capture hostile actors while ensuring minimal collateral casualties.

- **Protection of Cyber-Physical Objects via Intelligent Capsaicin-Polymer Composites:** In contemporary network-centric warfare, safeguarding the physical integrity of subterranean communication nodes, quantum transmission lines, and strategic data centers is of paramount importance. Low-grade capsaicin chemical groups isolated from local agricultural waste are structurally incorporated into the outer polymer composite sheathing of high-voltage and fiber-optic cables. When any biological vector – such as destructive rodents – attempts to compromise the cable asset, the nociceptors within its oral cavity immediately register an ultra-high chemical pain threshold, instantly deterring the behavior. This methodology represents a highly cost-effective and environmentally sustainable mechanism for protecting critical national military communication architectures against physical cyber-diversions.

Owing to its favorable agricultural yield potential and distinct regional climate parameters, the Republic of Uzbekistan exhibits exceptional capabilities for cultivating hot pepper (*Capsicum annuum*). Institutionalizing the deep phytochemical extraction and processing of this raw material asset within the domestic industrial base unlocks vast military-strategic and economic horizons.

Currently, the tactical lachrymatory agents and defense aerosols required by national law enforcement agencies and defense sectors are imported from external markets. By leveraging supercritical carbon dioxide extraction (SCCO_2 extraction) technology to isolate high-purity capsaicinoids from indigenous pepper cultivars (such as “Kok Qalampir”, “Chonchar”, etc.), it becomes highly

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feasible to engineer national tactical defense assets under the "Made in Uzbekistan" industrial framework. This strategic localization model substantially optimizes national defense budget allocations.

At present, the Radiation, Chemical, and Biological Protection Cycle within the Department of Combat Support at the University of Military Security and Defense of the Republic of Uzbekistan is executing applied research initiatives aimed at capitalizing on the defensive attributes of this local raw material. Specifically, the chemical modeling and tactical deployment of a non-lethal lachrymatory agent synthesized directly from the biomass of the indigenous "Margilan-333" hot pepper cultivar is being successfully realized (Table 1).

Table 1. Chemical Modeling and Practical Implementation Matrix

| Strategic Direction | Technological Mechanism | Defense Significance |
|--|--|---|
| Supercritical CO_2 Extraction | Developing production lines designed to extract Oleoresin Capsicum from raw biomass utilizing pure, ecologically sustainable CO_2 gas completely free from synthetic chemical solvents. | Establishing a standardized foundation for manufacturing high-purity, military-grade tactical gels and aerosols at an industrial scale. |
| Import Substitution and Autonomy | Engineering and manufacturing national tactical assets based on indigenous raw cultivars, specifically the local Margilan-333 strain. | Achieving absolute structural autonomy and eliminating import dependence on foreign protective sprays and non-lethal munitions within the Ministry of Internal Affairs, State Security Service, and National Guard. |
| Export Potential (SHU Scale) | Systematically standardizing and calibrating raw material profiles exhibiting ultra-high pungency thresholds according to the Scoville Heat Units (SHU) scale. | Supplying high-grade, standardized phytochemical components and non-lethal agents to international defense sectors and global pharmaceutical markets. |

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Capsaicin exerts a potent physiological impact not only on humans but also on animals and rodents. To protect military depots, communication cables, and underground strategic infrastructures from rodent infestations, capsaicin compounds extracted from local hot peppers are integrated into their polymer sheathing during the manufacturing phase. Cables and communication lines treated with capsaicin resist rodent damage, thereby enhancing the cyber-physical security of military communication networks.

Hot pepper extracts with high pungency thresholds according to the Scoville Heat Units (SHU) scale are in exceptionally high demand in the global marketplace, particularly within international defense and pharmaceutical industries. If local agro-industrial complexes establish the cultivation of high-concentration raw materials based on defense procurement orders, Uzbekistan could emerge as a strategic exporter of non-lethal weapon components in the region.

Hot pepper, seemingly a mundane element of the agricultural sector, manifests as a high-tech and strategic raw material asset within contemporary cyber-didactic and military-tactical paradigms. The neurobiological properties of its constituent capsaicinoids enable a controlled and safe restriction of human sensory systems, establishing the foundational cornerstone of the non-lethal weapons industry.

Implementing a deep phytochemical and engineering processing system for local pepper raw materials within the defense industry complex of the Republic of Uzbekistan liberates national security frameworks from import dependence. This integration of digital technologies, chemical localization, and agricultural capabilities serves as a fundamental methodological basis for expanding the tactical options of the armed forces and erecting effective cognitive-tactical barriers against asymmetric threats at minimal economic expense.

Local hot pepper biomass and its phytochemical constituents have transformed into a strategic non-lethal weapon agent as a result of contemporary military-strategic and nanotechnological innovations. Its microencapsulated formulations

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and integration into drone ecosystems provide the armed forces with high adaptability and execution precision in multi-domain operations.

Localizing the deep scientific-engineering processing system of local pepper raw materials within the defense industry of the Republic of Uzbekistan establishes a baseline foundation for engineering innovative equipment and protective assets that align with "Green Defense" standards. This approach liberates the national military from import dependence, acting as the most promising methodological driver for constructing a highly innovative defense framework against asymmetric and cyber-physical threats with minimal economic investment.

Advanced military and empirical analyses indicate that effectively exploiting the defensive properties of hot pepper, as a local phytochemical raw material, yields the following strategic and tactical opportunities within the defense architecture:

1. Hyper-Realistic Training Scenarios: Leveraging the properties of hot pepper to organize military readiness and CBRN (Chemical, Biological, Radiological, and Nuclear) training exercises, specifically accelerating personnel proficiency in using individual protective equipment (gas masks) under safe yet real-world simulated gas environments.

2. Psychological Inoculation: Cultivating cognitive stability and situational awareness reflexes in military personnel as they actively navigate terrains realistically contaminated by simulated adversary chemical agents during combat readiness field exercises.

3. Humanitarian Tactics: Securing maximum preservation of life for both hostages and rioters during tactical crowd control deployments and specialized operations.

4. Counter-Terrorism Operations: Successfully executing counter-terrorism and anti-diversionary reconnaissance team operations within enclosed architectural configurations and severe temporal deficits.

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5. Strategic Autonomy: Designing national chemical formulations of non-lethal, safe lachrymatory agents and their autonomous drone-delivery configurations, thereby ensuring the military-economic self-reliance of the state.

This synergetic integration of digital technologies, nanotechnological microencapsulation, and local agro-industrial potential serves as a fundamental methodological foundation for expanding the tactical capability of the armed forces and constructing a highly innovative defense network capable of responding effectively to the non-linear dynamics of contemporary multi-domain warfare at minimal economic cost.

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