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Article

Optimizing Azoxystrobin and Popiconazole Mixture in Suspoemulsion Formulation Using Selected Surfactants

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Abstract: The current study produced suspoemulsion formulations of azoxystrobin 6% + propiconazole 10%, resulting in a more responsible approach to crop protection. SE's physical and chemical properties were examined utilizing numerous tests and HPLC for active ingredient analysis, according to CIPAC techniques. Our results indicated that three SE formulations had the optimum physical properties. The SE formulations were C3, C1, and A2, respectively. The sample C3 SE was prepared using azoxystrobin 25% SC (24%), propiconazole 25% EC (40%), soltex 6% thickener (7.3%), and up to 100% of distilled water. While C1 SE was formulated using Azoxystrobin 25% SC (24%), Propiconazole 25% EC (40%), Thickener 6% sol (9.3%), and up to 100% of distilled water. However, the optimum SE formulation that succeeded in both the physical and chemical tests was A2, which was developed using azoxystrobin 25% SC (24%), propiconazole 25% EC (40%), thickener 6% sol (9.3%), and up to 100% of distilled water. Sample SE (A2) was the only sample that had an appropriate active ingredient concentration for azoxystrobin before and after storage (5.814% and 5.729%, respectively), as well as propiconazole 10% before and after storage (10.138% and 9.945%, respectively).

Keywords: Suspoemulsions, Surfactants, Azoxystrobin, Propiconazole.

1. Introduction

Agrochemical formulations are crop protection systems that come in a variety of forms and are designed to serve a specific function. A surface-active agent, commonly known as a surfactant, is required in each of these formulations. This is not only important for preparation, but also for maintaining the formulation's long-term physical stability (Castro *et al*., 2013; Chuacharoen *et al*., 2019). Recently, research on formulation and application technologies has become more vital. biological efficacy is dependent on formulation type and characteristics, thus should their improved. To be profitable, the formulation requires satisfying biological efficiency, storage stability, health and cost parameters (Quintero and Andrade, 2025). To improve the efficacy of pesticide formulations, the active ingredient must be equally dispersed across the application surfaces with maintaining chemical homogeneity (Quintero and Andrade, 2025). Surfactants make pesticides get to their intended target and increase the active ingredients effectiveness (Castro *et al*., 2013).

Suspoemulsion formulations (SE) are water-based products combining suspension concentration (SC) and concentrated aqueous emulsion (EC) technologies. It combines active chemicals with different solubilities or melting points into a single formulation to provide a wider spectrum of pest control, and storage stability and anti-foaming ability with avoiding the disadvantage of tank-mix incompatibility (Quintero and Andrade, 2025; Ohkouchi and Tsuji, 2022; Tharwat, 1937). Suspoemulsions require two types of surfactants: an emulsifier to emulsify oily liquid technical substances and a dispersion to disperse solid technical substances. As a result, selecting correct surfactants is extremely crucial, and developing pesticide formulations can be a chal-

lenging science (Ohkouchi and Tsuji, 2022). Azoxystrobin ((methyl)-2-{2-[6-(2-cyanophenoxy) pyrimidin-4-yloxy] phenyl}-3- methoxyacrylate) and Propiconazole ((±)-1-[2-(2,4-dichlorophenyl)-4-propyl-1,3-dioxolan-2-ylmethyl]-1H-1,2,4-triazole) are a systemic fungicides with different modes of action. Azoxystrobin belongs to the class of the strobilurin. Since its introduction in 1996, Azoxystrobin has fungicidal effect by disrupt mitochondrial respiration in fungi through the inhibition of complex III (FAO, 2015; Swiêci£o *et al*., 2018). While, Propiconazole is a triazole-based systemic fungicide. It is a strong inhibitor of ergosterol production. Ergosterol, a primary sterol in most fungi, is an essential component in membrane structures (Kassaw *et al*., 2021; FAO, 1993). This study aims to develop suspoemulsions of Azoxystrobin 6% + propiconazole 10%, using different surfactants, providing a more responsible approach to crop protection.

2. Materials and Method

2.1. Tested materials

2.1.1. Active ingredient

A. Azoxystrobin ($C_{22}H_{17}N_3O_5$) 96.5% purity obtaind from Flagchem International

B. Propiconazole ($C_{15}H_{17}C_{l2}N_3O$) 95% purity from Fjiangsu Sevencontinent Green chemical.

2.1.2. Surface-active agents

Polycondensation product, Polycondensation product, Condensed alkylnaphthalene sulphonate, Ethoxylated fatty alcohols and Ethoxylated tristyrylphenols phosphates), Emulsifiers (Ethoxylated castor oils, Ethoxylated tristyrylphenols and Dodecylbenzene sulphonates). Additionally, Ethylene glycol asAnti-freezing agent, a non-ionic aqueous emulsion based on polydimethylsiloxane oil as anti-foaming agent 2,4dinitrophenylhydrazone as Preservative agent.

2.2. Preparation of azoxystrobin 25% as suspension concentrates (SC) using different types of surfactants

Suspension concentrates were prepared using Silverson homogenizer, model L5M-A (used for Homogenizing SC Formulation). A Bead mill, model Vibromac (SM-PILOT-I-R-6X) was used for Milling SC Formulation, as shown in Table 1.

Table 1. Composition of three trial formulations for preparation of Azoxystrobin 25% as Suspension concentrate (SC) using different surfactants.

Components	(Volume W/V)		
	1*	2*	3*
Azoxystrobin 96%	78.12	78.12	78.12
ethylene glycol	21	21	21
a non-ionic aqueous emulsion based on	3	3	3
2,4dinitrophenylhydrazone	0.3	0.3	0.3
Polycondensation product	12	-	-
Condensed alkylnaphthalene sulphonate	-	4.5	-
Ethoxylated fatty alcohols	-	1.5	1.5
Ethoxylated tristyrylphenols phosphates	-	-	9
Distilled water	Up to 300 ml		

*1, 2 and 3: mean different formulation trials in type of dispersing agents used.

2.3. Preparation of propiconazole 25% as emulsifiable concentrate (EC) using different types of Surfactants

The Emulsifiable concentrate was prepared using Silverson homogenizer, model L5M-A that was used for homogenizing the EC (Table 2).

Table 2. Composition of three trial formulations for preparation of Propiconazole 25% as emulsifiable concentrate (EC) using different surfactants

Components	(Volume W/V)		
	A*	B*	C*
Propiconazole 95%	52.63	52.63	52.63
Emulsifier (Blends) 1	7	-	-
Emulsifier (Blends) 2	5	-	-
Ethoxylated castor oils	-	20	-
Ethoxylated tristyrylphenols	-	-	15
Dodecylbenzene sulphonates	-	-	3
Aromatic-hydrocarbons C9	Up to 200 ml		

*A, B and C: mean different formulation trials in the emulsifiers used.

2.4. Preparation of the new suspoemulsion formulation by mixing both azoxystrobin 6% and propiconazole10% using different types of surfactants

During the formulation process, the target concentrations of 6% and 10% were attained by mixing the produced Azoxystrobin SC and Propiconazole EC in precise ratios. Various concentrations of thickener (Soltex 6%) were evaluated in order to optimize the process. To reach the final volume of 150 ml, distilled water was added.

Table 3. Formulation Compositions of Azoxystrobin 6% + Propiconazole 10% as Suspoemulsions (SE) using different surfactants

Formulations	Samples SE (volume *w/v*)								
	A1	A2	A3	B1	B2	B3	C1	C2	C3
Azoxystrobin 25% SC	36	36	36	36	36	36	36	36	36
Propiconazole 25% EC	60	60	60	60	60	60	60	60	60
Soltex 6% Thickner	15	14	14.5	15.3	16.5	16	14	12	11
Distilled water	Up to 150 ml								

2.5. Physico-chemical properties of (azoxystrobin 6% + propiconazole 10%) SE formulations

a) Free acidity or alkalinity (pH test): was determined according to. (CIPAC, MT 75.3)

b) Persistent foam Test: was measured using Graduated Cylinder glass stoppered, 250 ml capacity according to. (CIPAC, MT 47).

c) Density Test: Mettler Toledo (Density meter), model Density Pro is used for the determination (CIPAC, F 18).

d) Viscosity Test: The viscosity was determined using AMETEK BROOKFIELD (Viscometer), Model DVNXRVCJG is used for the Determination. (CIPAC, MT 192)

e) Pourability test.: Test Cylinder a 500 ml stoppered measuring Cylinder It was carried out in accordance with (CIPAC, MT 148).

f) Himadzu HPLC model LC-2030C 3D plus is used for the Chemical analysis of Active ingredients. Column (Shim-pack GIST C18 column 250 mm x 4.6 mm, 5 µm) and Detector (LC-2030/2040 PDA) were used

These Physical properties tests have been performed on Azoxystrobin 6% + Propiconazole 10% SE according to CIPAC (Collaborative International Pesticides Analytical Council)

3. Results

CIPAC reported that compositional characteristics such as pH and viscosity, were critical for stability. it is vital to notice that these systems interact with one another, creating a dynamic and complicated system. Data in Table 4 indicated that the most suitable pH was for sample B1 according to CIPAC. Sample B1 (SE) exhibited the most suitable pH, where, ph were recorded 3.7

before storage and 3.96 after storage. In contrast, sample A1 gave the least suitable one. Sample B1 was formulated using Azoxystrobin 25% SC (24%), Propiconazole 25% EC (40%), soltex 6% Thickener (10.2%) and distilled water (up to 100%). However, Foam Volumes before and after Storag in B1 were 32 and 26 ml, respectively. Sample C3 (SE) exhibited the most acceptable persistent foam volume after 1 min, which was 10 and 8 ml before and after storage respectively.

Table 4. Physicochemical Stability of SE Formulations: pH and Foam Volume Analysis Before and After Storage

Sample (SE)	PH		Foam volume (ml) after (1 min)	
	Before Storage	After Storage	Before Storage	After Storage
A1	7.7	4.3	8	20
A2	5.2	4	8	20
A3	4.4	4.3	30	22
B1	3.7	3.96	32	26
B2	3.5	3.8	22	14
B3	3.6	3.8	36	8
C1	5.6	3.98	18	10
C2	4.9	4.46	8	30
C3	4.5	4	10	8

The present results in Table 5 illustrate that the most acceptable density was recorded in sample B3 (1.005 g/cm^3 before storage and 1.008 g/cm3 after storage). Furthermore, Sample B3 had the most acceptable viscosity of 209.5 and 212.6 cp before and after storage, according to CIPAC. The sample B3 SE was formulated by Azoxystrobin 25% SC (24%), Propiconazole 25% EC (40%), soltex 6% Thickener (10.6%) and up to 100% of distilled water. Sample B3 had the highest appropriate viscosity of 209.5 cp before storage and 212.6 cp after storage. The sample B3 SE was formulated using Azoxystrobin 25% SC (24%), Propiconazole 25% EC (40%), Thickener 6% sol (10.6%) and up to 100% of distilled water. Viscosity in Sample A3 SE decreased after storage from 209.5 to 129 cp. Sample C2 had the lowest viscosity after storage (37.21 cp).

Table 5. Impact of physico-chemical parameters of SE (suspoemulsion) formulations: Density and Viscosity before and after storage

Sample (SE)	Density (g/cm^3)		Viscosity (cp)	
	Before Storage	After Storage	Before Storage	After Storage
A1	1.019	1.033	33.07	109.1
A2	0.954	0.996	66.15	99.22
A3	1.005	1.011	209.5	129
B1	0.971	0.982	208.4	148.8
B2	0.968	0.995	138.9	124
B3	1.005	1.008	209.5	212.6
C1	0.939	0.962	198.4	187.4
C2	0.929	1.034	143.3	37.21
C3	0.998	1.042	88.2	141.7

Our findings revealed that A1 and C1 (SE) had the least residue and were rinsed the most. Sample A1 recorded 2.23 before and 2.36 after storage, as shown in Table 6. The sample A1 SE was formulated using Azoxystrobin 25% SC (24%), Propiconazole 25% EC (40%), Thickener 6% sol (10%) and up to 100% of distilled water. Sample C1 recorded 0.29 before storage and 0.19 after storage in rinsed residue. The sample C1 SE was formulated using Azoxystrobin 25% SC (24%), Propiconazole 25% EC (40%), Thickener 6% sol (9.3%) and up to 100% of distilled water.

Table 6. Evaluation of pourability and residual behavior of SE formulations containing Azoxystrobin 6% and Propiconazole 10% before and after storage

Sample (SE)	Residue (%)		Rinsed Residue (%)	
	Before Storage	After Storage	Before Storage	After Storage
A1	2.23	2.36	0.39	0.53
A2	2.39	2.37	0.23	0.28
A3	4.26	4.83	0.59	0.65
B1	4.83	3.52	0.47	0.72
B2	5.57	4.39	0.82	0.95
B3	2.11	2.48	0.39	0.47
C1	9.13	8	0.29	0.19
C2	6.07	5.70	0.43	0.23
C3	2.33	2.59	0.63	0.39

Table 7 indicated acceptable values of ±5 for Azoxystrobin 6% (5.7%-6.3%) and Propiconazole 10% (9.5%-10.5%). It proved that sample A1 and C1 SE were below the analysis allowed range (5.7%-6.3%) for Azoxystrobin 6% both before and after storage, whereas sample C3 was below the acceptable limit for the active ingredient azoxystrobin 6% after storage. All the SE formulations were within the acceptable range of active ingredient content for Propiconazole10% (9.5% - 10.5%) before and after storage. Although sample C3 had the finest physical features, its analysis after storage fell outside of the acceptable range for the active ingredient content (5.627%) for azoxystrobin. The second-best SE formulation fell beyond the acceptable limit for azoxystrobin before and after storage (5.666% and 5.603%, respectively). However, the third best suspoemulsion formulation was A2, which showed that it fell within the acceptable range for active ingredient content for azoxystrobin before and after storage (5.814% and 5.729%, respectively), making A2 the best formula both in physical and chemical properties for the SE formulation of Azoxystrobin 6% + Propiconazole10%.

Table 7. Stability of active ingredient content in se formulations of Azoxystrobin 6%and propiconazole 10% before and after storage

Sample (SE)	**Azoxystrobin 6%**		**Propiconazole 10%**	
	Before Storage	After Storage	Before Storage	After Storage
A1	5.642%	5.565%	9.852%	9.734%
A2	5.814%	5.729%	10.138%	9.945%
A3	5.838%	5.717%	10.192%	9.972%
B1	6.044%	5.941%	10.402%	10.281%
B2	6.083%	6.002%	10.494%	10.376%
B3	5.838%	5.702%	10.067%	9.831%
C1	5.666%	5.603%	9.863%	9.746%
C2	5.790%	5.714%	10.039%	9.930%
C3	5.750%	5.627%	9.987%	9.769%

4. Discussion

Agrochemical manufacturers are finding that formulation is a crucial technology that helps them differentiate their products and create substantial value in the face of many pressures on product performance. Brand refreshment is largely influenced by the launch of new products, and new formulation technologies can have a significant impact on this. Products that are comparatively safe and environmentally friendly are the outcome of some formulation type alterations as well as ongoing trends in new formulation processes that combine polymers and surfactants in creative ways (Hazra, 2017). Globally, a great deal of effort is being put into creating novel formulation technologies that will help achieve the goals of simpler application, labor savings, enhanced

safety, decreased toxicity, less environmental pollution, increased efficacy, and lower cost. Suspoemulsion, oil dispersion, microemulsions, granules, microgranules, water dispersible granules, concentrated emulsions, controlled release, gels, tablets, and suspension concentrates are among the areas under development (Hazra, 2019).

The suspoemulsion (SE) formulation is a recent advancement in formulation. Formulation chemists are able to combine active compounds with very different solubility profiles. This makes it possible to employ blends of active ingredients to create pest control products with a wider range of applications. By combining the active substances in one formulation, tank mixing is not necessary (Quintero and Andrade, 2025; Tharwat, 1937). Suspoemulsion formulation physical and chemical properties need to conform to the requirements of FAO according the FAO specifications for these particular formulation types to be regarded as successful formulations. These specifications can be found on the FAO. According to FAO specifications, the most significant physical tests in the SE formulations were persistent foam, density, viscosity, and pourability (residue) and (rinsed residue) tests. In line with a few investigations, combination systems with dispersed particles and surfactants have low contact angles, which significantly improve wetting. Similarly, these interactions contribute stabilize the emulsions. This principle is employed to the preparation of this SE (Quintero and Andrade, 2025). The Surfactants selection and ratios are critical for preventing aggregation and maintaining homogeneity in SE (Crimson Publishers, 2023). Surfactant type and ratio directly affect emulsion morphology, stability under stress, and phase separation resistance. (Trivana *et al*, 2021). The viscosity of a formulation is essential for simple handling and successful spraying after dilution. In the current analysis, the best SE formulation was the A2 sample. A2 had viscosity values of 66.15 and 99.22 cP before and after storage. Nevertheless, another investigation revealed that the viscosity of emamectin benzoate SE was 170 cP, which is relatively high for a sprayable formulation (Quintero and Andrade, 2025). Thus, when applied in the field, this SE provides the best spray ability and active ingredient distribution on the targeted areas. Additionally, Sample SE (A2) confirmed its physicochemical persistence before and after storage, showing its capacity as a competitive and sustainable commercial.

5. Conclusions

Azoxystrobin and propiconazole are active ingredients with fungicidal activity and distinct mechanisms of action. This study advances by generating a stable suspoemulsion in which various active components are combined. Our findings showed that the optimal SE formulation was Azoxystrobin 25% SC (24%), Propiconazole 25% EC (40%), Thickener 6% sol (9.3%), and up to 100% distilled water. This not only provides convenience to the farmer, but it may also result in synergistic biological effectiveness. As a result, a broader range of disease control can be obtained, particularly when multiple fungicides are used. Suspoemulsions often include an adjuvant to improve biological effectiveness. Future study could include bioassays and photostability testing of this formulation in different environments. As well as its impact on local ecosystems. Similarly, comparison assessments of the agronomic performance of this SE formulation with existing conventional formulations are needed to confirm its commercial feasibility

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